U.S. Mines, Bureau of

Bulletin 13

DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

JOSEPH A. HOLMES, Director

RÉSUMÉ OF PRODUCER-GAS INVESTIGATIONS

OCTOBER 1, 1904–JUNE 30, 1910

BY

R. H. FERNALD

AND

C. D. SMITH

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no. 13

NGINEERING

NGIN STORAGE

WASHINGTON
GOVERNMENT PRINTING OFFICE
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RÉSUMÉ OF PRODUCER-GAS INVESTIGATIONS.

OCTOBER 1, 1904–JUNE 30, 1910.

By R. H. Fernald and C. D. Smith.

INTRODUCTION.

By R. H. Fernald.

PLAN AND PURPOSE OF INVESTIGATIONS.

When the United States Geological Survey began operations at the coal-testing plant erected at the Louisiana Purchase Exposition at St. Louis, Mo., in 1904, it had already outlined a comprehensive plan for the systematic study of coals, lignites, and other mineral fuels with reference to their suitability for particular purposes and the methods by which they could be utilized most efficiently. Recognizing the need of information on the relative economy of producer gas as compared with steam for power purposes and the lack of comparable tests of American coals in the gas producer, the Geological Survey undertook investigations of the merits of different coals as producer fuel for the purpose of promoting efficiency in the utilization of the nation's fuel supplies. These investigations were carried on at St. Louis, Mo., and, later, at Norfolk, Va., and Pittsburg, Pa.

The act of Congress approved May 16, 1910, transferred the fuel-testing work being carried on by the Geological Survey to the Bureau of Mines. This bureau is conducting producer-gas tests at Pittsburg, Pa., and is publishing and distributing reports relating to all the fuel tests made by the Survey.

These investigations into the possibility of generating producer gas in a commercial way for power purposes from the various fuels of the country have been associated with steaming, briquetting, coking, and other tests, all of which supplemented an examination into the nature, extent, and distribution of the fuels. The tests have all been made with carefully selected representative samples and carload lots of materials procured specially for the purpose by experienced collectors.

The investigations promise to yield a particularly important result—the development of greater efficiency in the use of all fuels. This result is of specific importance in States remote from coal supplies, for example, in New England, where the rapid growth of various industries in the last few years has made the coal problem important. No coal is mined in that part of the country, the supply coming from Pennsylvania, West Virginia, and Virginia, and a little of it from Canada. Thus manufacturers in New England have to pay for transporting fuel from the coal fields and yet compete with manufacturers who have coal at their doors. This condition has led to the general discussion of the coal problem in the New England States and even to the appointment of committees of manufacturers to consider methods of relief.

The investigations made by the United States Geological Survey and the Bureau of Mines indicate that marked economies can be gained by a general use of the gas producer in New England and, moreover, that these economies will be sufficient to overcome the handicap placed on the industries there by coal transportation charges. In 1902 the coal consumed to produce steam power for manufacturing purposes in the New England States cost approximately $50,000,000, and the annual fuel bill of these States now approximates $100,000,000. The development of this power through the more efficient method suggested by these investigations would mean a yearly saving of many millions of dollars.

Many States of the West that have no good coal are also greatly benefited by the investigations, which have shown the adaptability of the gas producer for the utilization of low-grade coal, lignite, peat, etc. As mined these fuels are not suited for use in boiler furnaces and will not bear long transportation, but the gas producer makes them of potential value. Thus the gas producer is an agency of conservation. It helps to keep low-grade coals from being permanently lost by being left in the mines in such condition as to make their future recovery impossible. In States in which deposits of low-grade coal, lignite, and peat are found the present cost of power, as developed in steam plants with coal that has been shipped a considerable distance, can be materially reduced by placing producer plants at the mines or bogs, so as to utilize these cheap low-grade fuels without cost of shipment, by generating electric current which can easily be transmitted to desired points within a wide radius.

REPORTS ALREADY PUBLISHED.

Producer-gas investigations, including a systematic examination of fuel values and the most economical methods of utilizing the coals and lignites of the United States, were undertaken at the coal-testing plant of the Geological Survey at the Louisiana Purchase Exposition at St. Louis in 1904. The results of the initial tests, showing that most American bituminous coals and lignites would make good producer fuel, were so encouraging that the investigations were continued as an essential part of the researches of the Survey in its examination of mineral fuels in the United States.

A preliminary report summing up the work of the producer-gas plant at the Louisiana Purchase Exposition was published in Bulletin 261, and a detailed description of the plant, the coals tested, and the methods of conducting tests and of computing results was given in Professional Paper 48, part 3. Brief summaries of the more important results of the tests made at St. Louis from May 1 to December 31, 1905, appeared in Bulletin 290. The period from January 1, 1906, to February 8, 1907, was similarly covered by Bulletin 332. At the latter date the St. Louis fuel-testing plant began to be dismantled in consequence of the closing out of the affairs of the Louisiana Purchase Exposition, and the producer-gas, steaming, and briquet equipments were moved to Norfolk, Va. This city was selected as the site of operations because it was desirable to test coals suitable for naval use and because buildings and materials were offered by the Jamestown Exposition Company.

After the close of the Jamestown Exposition the principal station for testing fuels and structural materials and for carrying on investigations relating to mine accidents was established by the Survey at Pittsburg, Pa. In taking up the producer-gas investigations at this point it was deemed wise to make a special study of low-grade fuels. The producer plant used at St. Louis and Norfolk was returned to the manufacturers in accordance with arrangements that had been made with the companies supplying it and a different type of plant was installed.

SCOPE OF THIS REPORT.

The tests which have been conducted are of two classes, (1) those made with the pressure-producer installation used at St. Louis and Norfolk, and (2) those made with the down-draft producer plant at Pittsburg. Detailed accounts of the tests of groups (1) and (2) form Parts II and III, respectively, of this report, Part I consisting of a general and detailed discussion of producer gas and producer-gas plants. The first portion of Part II covers the following tests:

(*a*) A résumé of the 24 tests made at St. Louis, originally described in Bulletin 261 and Professional Paper 48, including a reproduction of the graphic logs and essential results.

(*b*) Short-time tests (138 in number) conducted at St. Louis on a large variety of bituminous coals and lignites from a wide extent of territory, including some of the principal coal fields of the United States. These tests were briefly summed up in Bulletins 290 and 332.

(*c*) Tests at Norfolk on coals which reach the seaboard at the shipping points of lower Chesapeake Bay and are largely used by the Navy and by the merchant marine.

The results of all these tests have been combined in making up the tables, but the methods of testing and the problems involved in the tests of group (*c*) differ so much from those of groups (*a*) and (*b*) that the details of procedure for the Norfolk work are presented as distinct chapter.

The problems taken up at the Pittsburg station during 1908 and 1909 involved new apparatus and a totally different method of procedure. On this account no attempt is made to combine the results of this work with those previously obtained, but, as already stated, the data for the Pittsburg work are presented as Part III of this report in order that the one bulletin may include a somewhat detailed account of the producer-gas investigations of the Survey from the beginning of the work on October 1, 1904, to the close of the fiscal year ended June 30, 1910.

The purpose of this report is, therefore, to present in convenient form all the more important data accumulated in the course of the tests described, in order that the results may be readily accessible both to Government officials having charge of the design, purchase, or care of power plants and to all persons interested in the development of the internal-combustion engine and the gas producer as means for utilizing the energy of fuels. It is believed that the results achieved with the equipment described are so full of promise as to call for more extended research. The efficiencies obtained show the possibilities of the gas producer as a factor in reducing waste in the use of coals and lignites and in conserving the fuel resources of the United States.

SUMMARY OF FUELS TESTED.

By means of the producer-gas plants 195 tests have been made. Bituminous coals, lignites, and peats from 28 different States were used, as indicated in Table 1.

TABLE 1.—*Classification of samples tested, by kind and locality.*

Locality.	Bituminous coal.	Subbituminous coal.	Lignite.	Peat.	Bone coal.	Miscellaneous.	Duplicate.	Total.
Alabama	3							3
Argentina						[a] 1	1	2
Arkansas	2		1					3
Brazil	1							1
California		1	1			[b] 1	2	5
Colorado		1						1
Florida				1				1
Illinois	29				1		2	32
Indiana	15						4	19
Indian Territory	2							2
Iowa	1							1
Kansas	2						1	3
Kentucky	5							5
Massachusetts				1				1
Michigan				1				1
Missouri	1							1
Montana		3						3
New Mexico	3							3
North Carolina				1				1
North Dakota			6				1	7
Ohio	10						1	11
Pennsylvania	16					[c] 1	4	21
Rhode Island						[d] 3	1	4
Tennessee	8						1	9
Texas			7				1	8
Utah	1	1						2
Virginia	6				1	[e] 1	3	11
Washington	1	3					1	5
West Virginia	16				2		2	20
Wyoming	5	1						6
Not designated:								
Coke breeze						1		1
Miscellaneous coke						1		1
Washery refuse						1		1
	127	10	15	4	4	10	25	195

[a] Slack.
[b] Lignite and cinders.
[c] Washery refuse.
[d] Anthracite.
[e] Pea anthracite.

Table 2 presents a condensed summary of the most important items relating to the coals and lignites tested in the gas producer. Figures are also given for Florida peat, although but one sample of it was received. It should be noted that in this table all items which are affected by the load factor are given only for loads ranging from 90 to 100 per cent of full load (235 brake horsepower for this plant).

The results of these tests, as given in the accompanying tables, have been subjected to absolutely no refinements. In general, only one test has been made on each sample, and the result of each test has depended to a great extent on the ability of the producer operator to become familiar with the method of handling the fuel during a period of eight or ten hours preceding the official test. It should also be borne in mind that all the St. Louis tests, whether on bituminous coal, lignite, or peat, have been made in producers of the same size and type—designed primarily for use with anthracite—and that the tests have necessarily been made and the required power has been generated without regard to the proper relation between the gas-producing qualities of the coal and the fuel-bed area. The tests have been conducted under the restrictions of a constant engine load (235 brake horsepower), and not with a view to determining the maximum power-producing quality of the fuel.

TABLE 2.—*Summary of important items in results of tests 1 to 169.*

Item.	Bituminous coal.							
	As fired.				Dry.			
	Tests averaged.	Average.	Maximum.	Minimum.	Tests averaged.	Average.	Maximum.	Minimum.
B. t. u. per pound, with 90 to 100 per cent load (tests over 30 hours)	112	12,372	14,674	9,338	112	13,228	15,073	10,656
Cubic feet of gas per pound	101	61.1	100.8	41.5	101	65.2	103.5	40.9
Pounds per square foot of fuel bed per hour	112	7.64	12.42	5.07	112	7.09	11.16	4.90
Pounds per E. H. P. per hour	112	1.52	2.93	.97	112	1.41	2.45	.95
B. t. u. per cubic foot of standard gas	112	150.9	176.0	120.2				
B. t. u. per B. H. P. per hour (full load)	101	11,418	14,700	9,516				
Pounds of tar, soot, etc., per ton of fuel as fired:								
Water not extracted	47	354	747	118				
Water extracted	13	287	624	92				
Composition of fuel (per cent):								
Moisture	112	6.66	14.77	1.36				
Volatile matter	112	32.78	42.46	14.72				
Fixed carbon	112	50.59	76.42	32.83				
Ash	112	9.97	21.73	2.67				
Sulphur (separately determined)	112	2.32	7.36	.28				
Volumetric analysis of gas (per cent):								
Carbon dioxide (CO_2)	112	9.71	14.80	6.33				
Oxygen (O_2)	112	.02	.59	0				
Ethylene (C_2H_4)	112	.19	.70	0				
Carbon monoxide (CO)	112	19.03	24.50	12.10				
Hydrogen (H_2)	112	13.48	18.60	7.20				
Methane (CH_4)	112	2.78	6.52	1.60				
Nitrogen (N_2)	112	54.79	63.46	48.30				

Item.	Sub bituminous coal.							
	As fired.				Dry.			
	Tests averaged.	Average.	Maximum.	Minimum.	Tests averaged.	Average.	Maximum.	Minimum.
B. t. u. per pound, with 90 to 100 per cent load (tests over 30 hours)	7	9,912	10,685	8,530	7	11,676	12,798	10,321
Cubic feet of gas per pound	6	39.3	45.9	32.1	6	45.9	52.8	38.8
Pounds per square foot of fuel bed per hour	7	11.02	14.78	8.46	7	9.32	12.22	7.56
Pounds per E. H. P. per hour	7	2.33	3.28	1.63	7	1.97	2.75	1.45
B. t. u. per cubic foot of standard gas	7	159.0	181.5	145.9				
B. t. u. per B. H. P. per hour (full load)	6	11,932	13,950	9,700				
Pounds of tar, soot, etc., per ton of fuel as fired:								
Water not extracted	2	259	260	257				
Water extracted	2	224	338	110				
Composition of fuel (per cent):								
Moisture	7	15.04	20.24	8.51				
Volatile matter	7	34.27	38.41	31.58				
Fixed carbon	7	39.44	45.69	28.76				
Ash	7	11.25	15.47	2.74				
Sulphur (separately determined)	7	.90	2.96	.47				
Volumetric analysis of gas (per cent):								
Carbon dioxide (CO_2)	7	11.16	13.40	8.00				
Oxygen (O_2)	7	.12	.55	0				
Ethylene (C_2H_4)	7	.20	.60	0				
Carbon monoxide (CO)	7	17.52	23.20	14.20				
Hydrogen (H_2)	7	14.41	19.30	10.50				
Methane (CH_4)	7	3.64	5.00	2.90				
Nitrogen (N_2)	7	52.95	59.20	46.50				

TABLE 2.—*Summary of important items in results of tests 1 to 169*—Continued.

Item.	Lignite.								Peat.		
	As fired.				Dry.						
	Tests averaged.	Average.	Maximum.	Minimum.	Tests averaged.	Average.	Maximum.	Minimum.	Tests averaged.	As fired.	Dry.
B. t. u. per pound, with 90 to 100 per cent load (tests over 30 hours)	7	7,112	7,603	6,356	7	11,059	11,473	10,346	1	8,127	10,289
Cubic feet of gas per pound.	5	27.7	31.9	25.2	5	43.2	47.1	40.7	1	30.3	38.3
Pounds per square foot of fuel bed per hour	7	13.28	15.72	11.91	7	8.55	10.09	7.21	1	16.2	12.0
Pounds per E. H. P. per hour	7	2.93	3.56	2.54	7	1.87	2.16	1.67	1	2.57	2.03
B. t. u. per cubic foot of standard gas	7	160.8	188.5	125.3	......	......	......	......	1	175.2	......
B. t. u. per B. H. P. per hour (full load)	5	11,434	13,770	9,970	......	......	......	......	1	12,840	......
Pounds of tar, soot, etc., per ton of fuel as fired:											
Water not extracted	6	157	289	66	......	......	......	......	1	240	......
Water extracted	......	......	......	......	......	......	......	......	1	157	......
Composition of fuel (per cent):											
Moisture	7	35.69	39.56	32.20	......	......	......	......	1	21.00	......
Volatile matter	7	29.25	33.15	26.49	......	......	......	......	1	51.72	......
Fixed carbon	7	27.16	29.55	24.37	......	......	......	......	1	22.11	......
Ash	7	7.90	11.42	5.04	......	......	......	......	1	5.17	......
Sulphur (separately determined)	7	1.12	3.54	.49	......	......	......	......	1	.45	......
Volumetric analysis of gas (per cent):											
Carbon dioxide (CO_2)	7	9.90	13.50	8.20	......	......	......	......	1	12.40	......
Oxygen (O_2)	7	.13	.70	0	......	......	......	......	1	0	......
Ethylene (C_2H_4)	7	.10	.70	0	......	......	......	......	1	.40	......
Carbon monoxide (CO)	7	20.86	25.20	14.00	......	......	......	......	1	21.00	......
Hydrogen (H_2)	7	14.30	15.60	9.20	......	......	......	......	1	18.50	......
Methane (CH_4)	7	2.88	4.85	2.40	......	......	......	......	1	2.20	......
Nitrogen (N_2)	7	51.83	60.90	48.70	......	......	......	......	1	45.50	......

Table 3 presents a classification of 103 coals into 10 groups (A to J), according to calorific value, each group embracing a range of 500 British thermal units, the medial figure of which is assigned as the approximate calorific value of the group (dry-coal basis). Average results relating to pounds of fuel burned, gas produced, producer efficiency, and plant duty (summarized from the number of tests shown by black-face figures under each group) are also given. The relative economic values may be modified slightly in the light of future tests conducted under improved conditions.

TABLE 3.—*Grouping of 103 coals according to their approximate calorific value (dry-coal basis), with summary of averages[a] of important economic results.*

Approximate calorific value.	Average length of test (hours).	Designation of coal (all samples run of mine except as otherwise indicated).	Coal per square foot of bed per hour (pounds).		Standard gas.			Producer efficiency (per cent).	Plant duty.				
					Per pound dry fuel.		B. t. u. per cubic foot.		Coal burned per hour (pounds).				B. t. u. from standard gas per B. H. P. developed.
									Per E. H. P. at switchboard.		Per B. H. P. developed.		
			As fired.	Dry.	Calorific value (B. t. u.).	Yield (cubic feet).			As fired.	Dry.	As fired.	Dry.	
15,000 (group A)	**4** 49.3	Virginia: 3 (l.), 4 (l.). West Virginia: 13, 14.	**4** 5.64	**4** 5.50	**3** 13,353	**3** 91.1	**4** 152.5	**1** 74.7	**3** 1.17	**4** 1.13	**4** 0.99	**4** 0.96	**3** 11,510
14,500 (group B)	**8** 50.0	Alabama: 6. Kentucky: 1 B (egg), 5, 6. Pennsylvania: 8. Tennessee: 2. Virginia: 2. West Virginia: 18.	**8** 6.10	**8** 5.92	**5** 12,462	**5** 80.5	**8** 159.8	**3** 74.2	**8** 1.28	**8** 1.24	**8** 1.08	**8** 1.05	**5** 11,710
14,000 (group C)	**20** 46.2	Ohio: 4 (l.), 5 (nut). Pennsylvania: 4 (l.), 5 B (nut), 6, 10 (¾ inch), 11, 12, 15, 16, 22. Tennessee: 3, 4, 5. Utah: 1. Virginia: 1, 6. West Virginia: 16 A (nut), 20, 25 (l.).	**20** 6.45	**20** 6.22	**20** 10,888	**20** 72.1	**20** 151.6	**20** 71.9	**20** 1.37	**20** 1.32	**20** 1.16	**20** 1.12	**20** 11,280
13,500 (group D)	**17** 46.2	Alabama: 4. Arkansas: 7 A (l.). Illinois: 11 D (No. 3 w.). Indiana: 11 (l.), 18 B (l.). Kansas: 5 (over ⅝ inch). Ohio: 3 (w.), 6, 7 (l.), 9 A (l.), 10 (l.). Pennsylvania: 6 A and B, 7, 13, 17. Tennessee: 8 A and B. Wyoming: 5.	**17** 6.97	**17** 6.54	**14** 10,073	**14** 67.8	**17** 149.7	**13** 69.3	**16** 1.53	**16** 1.45	**16** 1.29	**16** 1.23	**14** 11,480
13,000 (group E)	**19** 48.1	Arkansas: 8 (4 inch). Illinois: 10 (s.), 11 A (egg), 13 (egg), 16 (l. and egg), 19 B (3-inch l.), 30 (w.). Indiana: 3 (nut and s.), 5, 7 A (nut, egg, and l.), 8 (l.), 9 A (over 1¼ inches), 15. Kentucky: 7 (l. and nut). New Mexico: 4 A, 5. Ohio: 12. Tennessee: 1, 7 A.	**19** 7.88	**19** 7.30	**18** 9.360	**18** 61.8	**19** 151.6	**18** 67.5	**19** 1.65	**19** 1.53	**19** 1.40	**19** 1.20	**18** 11,400

12,500 (group F)	[b]**17**	74.5	Illinois: 8 (nut), 9 B (l.), 11 C (egg), 18 (l. and egg), 19 C, 21 (l.), 23 B (s.), 24 B (l.). Indiana: 6, 12, 13, 16. Kansas: 6 (l.). Ohio: 8, 11 (l.). Virginia: 5 A (pea anthracite). Washington: 2 (l.).	**17**	8.76	**17**	7.84	**16**	8,770	**16**	58.6	**17**	149.2	**16**	65.0	**17**	1.92	**17**	1.72	**17**	1.63	**17**	1.46	**16** 11,600
12,000 (group G)	**11**	47.9	Illinois: 14 (l.), 15 (l. and egg), 22 A (l.), 23 A (5-inch l.), 25 (l.), 27, 29 B. Indiana: 14. New Mexico: 3 A. Tennessee: 6. Wyoming: 4.	**11**	8.54	**11**	7.69	**9**	8,776	**9**	59.4	**11**	147.9	**9**	67.6	**11**	1.91	**11**	1.72	**11**	1.63	**11**	1.47	**11** 11,810
11,500 (group H)	**3**	46.7	Illinois: 6 B (l.), 7 B (nut and pea), 26.	**3**	10.11	**3**	8.88	**3**	8,008	**3**	54.8	**3**	145.9	**3**	64.3	**3**	2.14	**3**	1.88	**3**	1.82	**3**	1.60	**3** 11,730
11,000 (group I)	**2**	41.0	Illinois: 7 C (s.). Wyoming: 2 B.	**2**	11.61	**2**	10.53	**2**	6,110	**2**	45.9	**2**	133.4	**2**	52.5	**2**	2.60	**2**	2.35	**2**	2.21	**2**	2.00	**2** 11,380
10,500 (group J)	**2**	29.0	Illinois: 7 A (s.). Wyoming: 3.	**2**	13.26	**2**	11.53	**2**	5,790	**2**	40.9	**2**	135.1	**2**	50.5	**2**	3.49	**2**	3.04	**2**	2.97	**2**	2.59	**2** 11,640

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[a] Black-face figures indicate the number of tests used in making the average given.

[b] One test of 562 hours.

CONTRIBUTIONS TO NATIONAL WELFARE.

CONSERVATION OF FUEL RESOURCES.

These tests in the gas producer have shown that many fuels of such low grade as to be practically valueless for steaming purposes, including slack coal, bone coal, and lignite, may be economically converted into producer gas and may thus generate sufficient power to render them of high commercial value.

Practically every shipment tested in the producers, including coals with ash as high as 44 per cent and lignites and peats high in moisture, has been successfully converted into gas that has been used in operating gas engines. It is estimated that on an average each coal tested in the producer-gas plant developed two and one-half times the power that it would develop if used in the ordinary steam-boiler plant. Such relative efficiencies probably hold good for the average installation of moderate power capacity, but the ratio is smaller when large steam plants of the most modern type are compared. It was found that the low-grade lignite of North Dakota developed as much power when converted into producer gas as did the best West Virginia bituminous coals when utilized under the steam boiler. Thus, through these investigations, lignite beds underlying from 20,000,000 to 30,000,000 acres of public lands, supposed to be worth little, have been shown to possess a large value for power development. As a result the money value of this Government land has been increased to the extent of probably $300,000,000 or more.

Investigations into the waste of coal in mining have shown that it probably aggregates 250,000,000 to 300,000,000 tons yearly, of which at least one-half might be saved. It has been demonstrated that the low-grade coals, high in sulphur and ash, now left underground, can be used economically in the gas producer for the ultimate production of power, heat, and light, and should, therefore, be mined at the same time as the high-grade coal. Moreover, attention is now being called to the practicability of further reducing this waste through more efficient mining methods.

ELIMINATION OF THE SMOKE NUISANCE.

The investigations herein reviewed also show that the general use of gas producers for the development of power means the practical elimination of the smoke nuisance. This result is especially important in cities that are compelled to use bituminous coals. At present several factors are working together to reduce the amount of smoke discharged into the atmosphere. Among these are:

(*a*) The elimination of numerous small, inefficient, poorly manipulated, individual house-heating plants by the introduction of district or central heating stations.

(*b*) The increasing use of electric power in factories, office buildings, and for miscellaneous purposes, and the resulting reduction in the number of small steam-power plants.

(*c*) The economic advantages that are bringing about the rapid introduction of producer-gas plants.

(*d*) The centralization of large producer-gas installations at the mines with the distribution of energy over extensive areas, either in the form of electric current or as gas.

As stated above, on the average 1 ton of coal in the gas producer will develop as much energy as 2½ tons in the ordinary steam plant. The great saving in fuel thus obtained has led to the installation within the last decade of several hundred producer-gas power plants throughout the United States. In the smaller plants anthracite is largely used, but bituminous coal and lignite are used in the larger installations. These producer plants are practically smokeless during operation. When fires are first kindled, more or less smoke is discharged, but after this preliminary period no smoke issues from the plant until it becomes necessary to clean the producer and rekindle the fires. In certain types of installations operating under suitable conditions the fires need not be drawn for months and at some plants not for years. It is no exaggeration to state that such plants are absolutely smokeless. In plants of other types, or under conditions that do not permit long periods of operation without shutting down, new fires are more frequently kindled, but even then it is rarely necessary to produce smoke oftener than once a week and then only for a short time.

As a smoke preventer, therefore, the gas producer is one of the most efficient devices on the market, and furthermore it reduces the fuel consumption, not 10 per cent or 15 per cent, as claimed for the ordinary smoke-preventing device offered for use in steam plants, but 50 to 60 per cent. Even the smoke which issues during brief periods from a producer plant is not objectionably black like that which comes from so many stacks in every industrial center. Architecture, too, gains, for the introduction of these plants tends to eliminate unsightly chimneys and in this way also promotes economy.

One of the objections that is commonly raised against the introduction of producer plants is that they do not offer any convenient method of factory or office heating. This undoubtedly has been true, but in the near future it will be possible to provide such heating with comparative ease and little expense from producer-gas plants. One or two recent installations offer notable examples of such heating.

The establishment of producer-gas plants at the mines and the distribution of electric energy or gas over large areas will also tend to eliminate smoke. Such central plants can deliver high-voltage current 250 miles away. The movement to install them is hastened by the rapid development in the use of electricity for manufacturing and power-plant purposes and in particular by the electrification of railroad terminals. When a large percentage of the small, isolated, smoke-producing power and heating plants and all steam locomotives have been removed from the larger cities, the atmosphere of these cities will be much clearer and heavy financial losses directly traceable to smoke will be eliminated.

PART I.

PRODUCER GAS AND PRODUCER-GAS PLANTS.

By R. H. FERNALD.

INTRODUCTION.

Nearly all gases used for power, heating, and lighting, except natural gas, are derived from the partial combustion or distillation of solid fuels or the vaporization of liquid combustibles. The fuels commercially employed for making producer gas are generally coal, coke, charcoal, lignite, and peat; but wood, sawdust, straw, oil, etc., may be advantageously used under certain conditions.

When coal is thrown upon a hot fire a portion of it immediately flashes into flame or passes off in the form of vapors and gases. This portion is commonly called volatile matter. The solid portion remaining is termed coke. It consists largely of carbon, but also contains some material that will not burn. This unburnable portion is the ash, clinker, or refuse that is removed from the grate or ash pit. These three parts of a fuel—volatile matter, carbon, and ash—are the most important factors in determining the character of the product in the manufacture of gas.

In the most familiar process of gas making, the manufacture of coal gas, the coal is subjected to destructive distillation. The resulting gas is high in illuminating qualities and has a relatively high heat value. In this process a valuable by-product is coke.

In another process of making gas from coal, a moderate supply of air, with or without water vapor or steam, is passed through a thick fuel bed. By the proper regulation of this air supply a partial or incomplete combustion of the fuel is maintained, resulting in the gradual consumption of all the combustible matter. The coke, instead of remaining as a by-product, as in the process previously mentioned, is utilized in making the gas. Gas generated by this method is known as producer gas, and the apparatus in which the gas is made is called the gas producer.

COMPOSITION OF PRODUCER GAS.[a]

CONSTITUENT GASES AND VAPORS.

The fuel gases resulting from the different systems of manufacture have the same essential constituents, but in so widely different proportions that they vary greatly in the range and the manner of their commercial application. They usually embody the following combustible and noncombustible constituents in different proportions: Combustible gases—hydrogen (H_2), carbon monoxide (CO), methane or marsh gas (CH_4), and ethylene (C_2H_4); noncombustible gases—nitrogen (N_2), carbon dioxide (CO_2), and oxygen (O_2).

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[a] *See* Clement, J. K., Adams, L. H., and Haskins, C. N., Bureau of Mines Bull. 7. 1911. 58 pp.

The heat value of any gas mixture is determined by the proportion and relative heat value of the individual combustible gases in it. The noncombustible gases, of course, add nothing to the heat value but act as diluents. Gases of the same general type often vary considerably in composition. As an illustration typical analyses of producer gas from two fuels utilized in the same producer plant are presented:

Composition by volume of pressure producer gas from two different fuels.

	From Montana lignite.	From Pennsylvania bituminous coal.
Hydrogen (H_2)	16.0	12.5
Carbon monoxide (CO)	14.2	20.7
Methane (CH_4)	2.9	2.5
Ethylene (C_2H_4)	.6	.0
Oxygen (O_2)	.2	.0
Carbon dioxide (CO_2)	13.2	8.7
Nitrogen (N_2)	52.9	55.6
	100.0	100.0
B. t. u. per cubic foot	147.5	140.6

Besides the constituents mentioned, many fuel gases contain vapors which do not appear in the analysis, but which may prove useful or detrimental in the commercial application of the gas. Many of these vapors are hydrocarbon compounds, the most familiar and important of which are tars.

As previously stated, producer gas is made by passing a moderate air supply through a thick fuel bed which is in a condition of partial combustion. Steam is generally added to the air blast, and the character of the gas developed depends largely upon the amount of steam used. Three types of producer gas may be generated in the same producer. When dry air alone is used the resulting gas is known as "air gas;" when the air introduced is charged with steam or water vapor the resulting gas is called "mixed gas;" and when the air is eliminated, that is, when steam alone meets the incandescent fuel bed, the resulting gas is termed "water gas."

REDUCTION OF CARBON DIOXIDE.

As may readily be seen, the simplest producer gas is made by passing dry air through a thick bed of burning carbon—commercially either charcoal or coke. If a producer is filled with charcoal or coke and a fire is kindled in the lower portion, as the dry air enters from below the oxygen of the air will combine with a portion of the carbon in the incandescent zone, thus supporting the combustion and developing carbon dioxide (CO_2). If this carbon dioxide passes through the deep bed of charcoal or coke (carbon) above the burning zone, and if the proper temperature prevails, it will be reduced to carbon monoxide (CO). This gas is the simplest of producer gases, but it has a low heat value and is difficult to produce economically on a commercial basis.

DECOMPOSITION OF STEAM.

The usual procedure in producer-gas making is to utilize coal as fuel and to add a certain amount of steam with the air. The steam not only has the effect of enriching the gas, but also tends to reduce the fuel-bed temperature, which otherwise may become too high for successful commercial operation. When steam meets an incandescent fuel bed it reacts with the carbon and theoretically forms carbon monoxide and hydrogen ($C + H_2O = CO + H_2$). The enrichment of the gas is due to this additional hydrogen. In the use of steam sufficient care must be exercised to prevent the chilling of the fuel bed to such a point that the necessary decomposition of the steam can not take place. It is possible to maintain combustion with air and at the same time to supply so much steam that the latter can not be completely decomposed owing to insufficient heat in the fuel bed. The result is usually an excess of carbon dioxide and the mechanical mixture of a certain portion of undecomposed steam with the gas issuing from the generator. The amount of steam that can be used to advantage is therefore small.[a]

TAR VAPORS.

When coal, especially bituminous coal, is used in place of coke considerable volatile material is usually distilled from the fresh coal at the top of the producer by the heat in the gas that passes up through the fuel bed. Besides the gaseous volatile matter or coal gas considerable tarry material is usually given off, which may or may not be objectionable, according to the method of using the gas. If these tarry products or hydrocarbon compounds are allowed to chill they may give difficulty in some plants, owing to their tendency to clog pipe lines, valves, engine governors, etc. Hence it is important, where producer gas is to be used for operating engines, that this tar be removed or be converted into combustible gases which may be utilized as a part of the regular gas output. The methods of handling these tar vapors will be discussed later.

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[a] *See* Clement, J. K., Adams, L. H., and Haskins, C. N., Bureau of Mines Bull. 7, 1911, p. 53.

FACTORS DETERMINING COMPOSITION.

The composition of producer gas varies greatly. The type of producer, the methods and skill used in operating, the uniformity and regulation of the air and steam supply, the kind and quality of fuel used, the depth of fuel bed, the distribution of the fuel, and the uniformity in size of the fuel are factors that affect the product. Typical analyses of producer gas presented in the advertising matter of manufacturers of gas producers signify little unless the details of the operating conditions are known. It is very difficult in ordinary practice to develop gas of the remarkably high quality usually listed in the catalogues of the various manufacturers.

Inasmuch as the investigations involved in this discussion relate almost entirely to bituminous coal, lignite, and peat, the following typical analyses of up-draft producer gas generated with these several fuels in a pressure-producer plant are submitted:

Typical analyses of up-draft pressure-producer gas.

[Per cent by volume.]

	From bituminous coal.	From lignite.	From peat.
Carbon dioxide (CO_2)	9.84	10.55	12.40
Oxygen (O_2)	.04	.16	.00
Ethylene (C_2H_4)	.18	.17	.40
Carbon monoxide (CO)	18.28	18.72	21.00
Hydrogen (H_2)	12.90	13.74	18.50
Methane (CH_4)	3.12	3.44	2.20
Nitrogen (N_2)	55.64	53.22	45.50

Similar analyses of the gases from corresponding grades of fuel in down-draft producers are also presented:

Typical analyses of down-draft producer gas.

[Per cent by volume.]

	From bituminous coal.	From lignite.	From peat.
Carbon dioxide (CO_2)	6.22	11.87	10.94
Oxygen (O_2)	.13	.01	.41
Ethylene (C_2H_4)	.01	.00	.06
Carbon monoxide (CO)	21.05	16.01	16.91
Hydrogen (H_2)	12.01	14.76	10.19
Methane (CH_4)	.49	.98	.66
Nitrogen (N_2)	60.09	56.37	60.83

As already pointed out, carbon monoxide, hydrogen, ethylene, and methane are desirable constituents in producer gas, and the suitability of the gas for a particular industrial application depends somewhat on the relative proportions of these constituents. Producer gas with a high percentage of hydrogen may be well adapted to certain metallurgical applications, but if the gas is to be used in internal-combustion engines the percentage of hydrogen must be kept within certain limits. For this reason the methods of operating producer plants for the generation of gas for power purposes are often quite different from those employed where the gas is to be used for metallurgical work.

As the preceding analyses show, the percentage of oxygen in producer gas is usually very small. Nitrogen has no special effect, but acts simply as a diluent. The presence of much carbon dioxide in the gas denotes undesirable conditions in the producer. It indicates the development of more heat than is required in the process of gas making. It also indicates that a portion of the carbon monoxide has been burned in the producer or that the fuel bed was not thick enough to reduce the carbon dioxide evolved in the incandescent zone to carbon monoxide before the gas left the producer. The principal cause of an excess of carbon dioxide is a fuel bed that is too shallow or is not hot enough to properly decompose the carbon dioxide produced in it; the latter condition usually denotes an oversupply of steam.

TYPES OF PRODUCER PLANTS.

GENERAL CLASSIFICATION.

Although, broadly, producer gas has two general applications—for power purposes and for metallurgical work—only the types of power-producer plants will be considered under this head. Three distinct types of these plants have been commercially manufactured in the United States: (*a*) The suction type; (*b*) the pressure type; and (*c*) the down-draft type. Besides these three a combination of the principles of up draft and down draft has recently been brought forward in the double-zone producer.

SUCTION PRODUCER PLANTS.

ESSENTIAL FEATURES AND PRINCIPLES.

As shown in figure 1 the essential parts of a suction-producer plant are the gas generator or furnace, the steam generator or boiler, and the gas cleaner or scrubber. A fire is made with shavings, wood, etc., on the grate, *a*, of the gas generator, the air necessary for combustion being supplied by means of the blower shown at *i*. As soon as the fire is sufficiently kindled the fuel to be used for gas making—charcoal, coke, or anthracite—is gradually charged into the producer. The blower for the air supply is driven by hand, or in large plants by electric or other power, until gas of sufficiently good quality to operate the engine is generated. The quality of the gas is roughly ascertained by means of a test cock at which the gas is lighted. As soon as the test flame shows the right color, which can be readily determined after a little experience, the gas is turned into the engine. The smoke and poor gas developed during the early stages of combustion are discharged into the outside air by means of the purge pipe shown at *c*. As soon as the engine is started, the blowing of the producer is stopped, and the necessary air for maintaining combustion is drawn into the base of the producer by means of the suction produced in the engine cylinder.

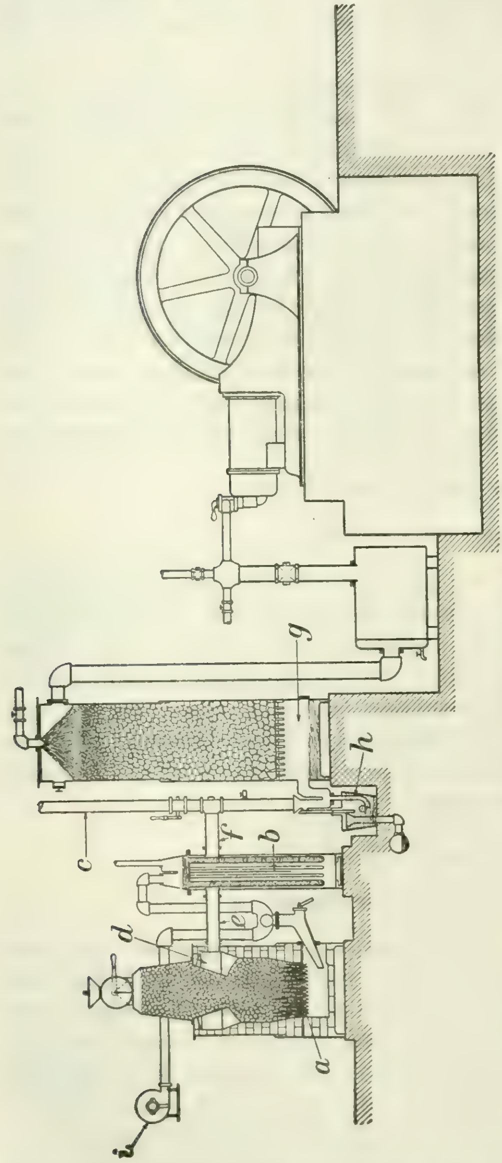


FIGURE 1.—Sectional view of suction gas-producer power plant.

If air alone is supplied, even in restricted quantities, the temperature of the fuel bed in the producer rises so high as to hinder the production of satisfactory gas. It is necessary therefore, as previously stated, to cool the fuel bed by adding steam. The methods of producing this steam vary in detail in plants of different design, but the principles involved are essentially the same.

At *b* is shown the steam generator or boiler for this particular type of producer. Steam at atmospheric pressure is generated by the heated gas, which leaves the producer at the point *d* and enters the boiler through the pipe *e* on its way to the scrubber. The steam thus generated is picked up by the air supply passing into the base of the producer. The mixture of air and steam is then drawn up through the incandescent fuel bed. The oxygen of the air and the oxygen of the steam combine with the highly heated carbon in the lower part of the bed, producing complete combustion and developing carbon dioxide. The gas thus formed passes up through a thick fuel bed above and the carbon dioxide is largely reduced to carbon monoxide. The hydrogen liberated by the decomposition of the steam greatly enriches the product.

SCRUBBING THE GAS.

The gas after leaving the boiler at the point *f* passes to the base of the scrubber *g*. The scrubber is usually a cast-iron or sheet-steel tower in which the dust, soot, tar, and other impurities are removed from the gas. As usually constructed it consists of a simple cylindrical shell filled with coke, over which water is sprayed. The dirty hot gas enters the base of the scrubber and flows upwards; it is divided, in passing through the coke, into separate streams which are met by a fine water spray flowing in the opposite direction. The gas and the water are thus brought into intimate contact and the particles of dirt and other foreign matter carried by the gas are largely washed out. The wash water from the scrubber passes into a water seal shown at *h*, from which it overflows into the drain, or, in large installations, into a settling basin or reservoir. If the gas is to be used in an engine it is essential that it be thoroughly freed from gritty material in order to prevent scouring of the engine cylinders. It is equally important that tarry compounds be removed, in order to prevent clogging of the engine valves and governor.

Ideas regarding the best method of cleaning the gas seem to vary greatly. At one extreme is a scrubber without coke or other solid material, completely filled with finely atomized water or fog, through which the gas passes. At the other extreme is a tall tower-like scrubber with the water pelting down in large drops or globules and supposedly beating the dust and dirt out of the gas. The ordinary practice, however, is to use coke-filled scrubbers and water spray.

The gas enters the scrubber at a relatively high temperature (500° to 1,000° F.) and leaves it at about atmospheric temperature, going to the engine as a comparatively dry, clean, cool gas. In some plants after the gas leaves the wet scrubber it is passed through a dry scrubber. This consists of a chamber filled with excelsior, shavings or other similar material which removes a large portion of the moisture and also tends to take out any of the impurities which may have escaped the water spray. In some plants this dry scrubber is placed in the top of the main scrubber shell above the water spray; in others it is placed on the gas line between the wet scrubber and the engine. Just before passing to the engine the gas is usually carried through some form of expansion chamber or regulating tank which serves to prevent serious fluctuations in the draft through the fuel bed and also tends to supply the engine uniformly with gas.

ACTION OF THE ENGINE.

The gas, together with enough air to form an explosive mixture with it, is drawn into the engine cylinder during the suction stroke. This charge is compressed on the return stroke of the piston, at the completion of which it is ignited by means of an electric spark. The hot gases produced by combustion tend to expand rapidly, producing pressure upon the piston during the third stroke, which is known as the power stroke. After the gas has expanded in the cylinder and the power stroke is completed, the piston moves forward on the fourth stroke, clearing out the burned gases through the exhaust port. The action of the engine may be more readily understood by reference to figure 2.

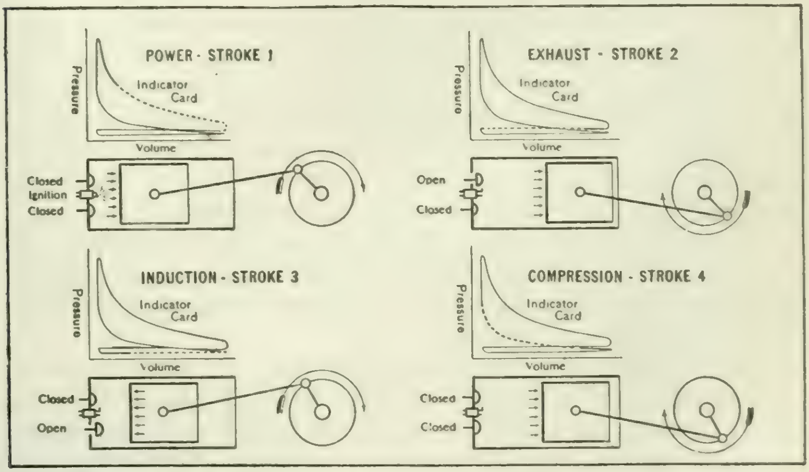
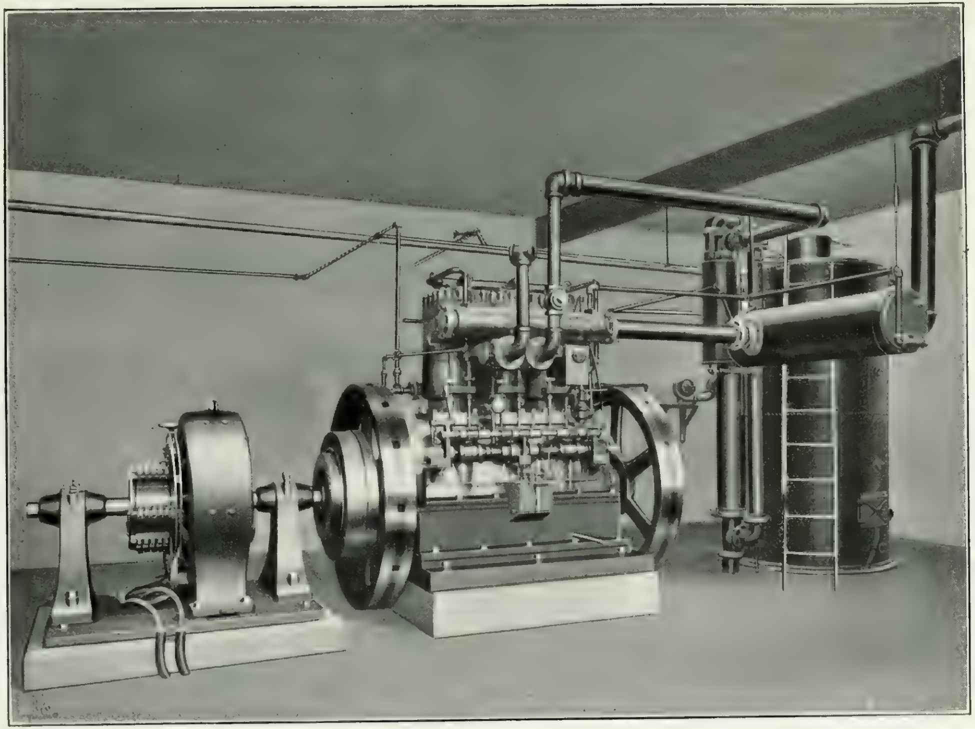


FIGURE 2.—Piston positions and indicator diagrams of a four-stroke gas engine.

One of the advantages of the suction type of producer is that the supply of air and steam passing through the fuel bed, and consequently the quantity of gas generated, is largely regulated by the demands of the engine. The designers of plants endeavor to procure simple automatic devices to produce this important theoretical condition in regular operation, and some of the plants on the market are extremely satisfactory in this respect. Because the air and steam are drawn through the fuel bed by the suction stroke of the engine, it is important that the resistance offered by the fuel bed, scrubber, and connections should at all times be as small as possible, so that the power available for commercial use may not be reduced more than is necessary by the draft requirements of the producer. Hence the grate must be kept free from accumulations of ash and clinker.



SUCTION GAS-PRODUCER POWER PLANT.

FUELS AVAILABLE.

It should further be borne in mind that any tarry products or other foreign matters that pass through the scrubber will be drawn directly into the engine cylinder, and that tar condensing in the engine valves or governor attachments interferes with the successful operation of the engine. For this reason fuels containing a large percentage of tar are not suitable for use in the suction producer. Hence the fuels regularly used in such plants are charcoal, coke, and anthracite. Even in the use of certain grades of coke and of anthracite there is a slight tar production that has to be guarded against. Numerous reports are made of the use of many special varieties of fuel in suction plants, but so far as is known there is at present no plant of the suction type successfully operating on a commercial basis with any but the standard fuels.

Because of the high price of the fuels generally used in them, suction plants, though numerous, are of comparatively small power, few exceeding 300 horsepower per unit and most of them not exceeding 100 horsepower. On account of this high fuel cost the demand for suction producers to operate on cheaper fuels such as bituminous coal, lignites, and peat is great, but comparatively little has been accomplished in this country toward satisfying this demand.

A typical installation of a suction-producer power plant is shown in Plate I. As will be noted, some of the details mentioned in the description accompanying figure 1 were designed along different lines for the type of plant represented in this plate.

PRESSURE-PRODUCER PLANTS.

DESCRIPTION OF ST. LOUIS PLANT.

General arrangement.—The up-draft pressure-producer type of installation is well illustrated by the plant used by the Geological Survey at St. Louis and Norfolk. Like the suction-producer plant, the up-draft plant has as essential parts a gas producer or generator, a steam generator or boiler, and a gas cleaner or scrubber. Certain additional features of the Survey plant, more or less necessary for proper manipulation, appear in the following description.

The plant was a Taylor pressure gas producer and was installed to generate 250-horsepower. Plate II shows the general arrangement of the plant. The boiler house, directly in the rear, was erected for steaming tests and was not directly connected with the producer-gas plant. At the extreme right is the gas-engine room. The exhaust pipe of the gas engine is seen projecting through the roof. Figures 3 and 4 show the plans and elevations of the different units of the plant as well as the general dimensions.

The producer.—In the catalogue published by the builders the specifications of the producer are as follows:

> Gas producer with rotative ash table; size No. 7; inside diameter of brick lining or jacket, 7 feet; area of fuel bed, 38.5 square feet; height of top of casing, 15 feet.

The producer (see Pl. III*A*) consisted of an iron cylinder 8 feet 6 inches in internal diameter and 15 feet high. The upper part of this shell was lined with approximately 2,800 wedge fire brick, the vertical depth of this lining being 10 feet 3 inches. The space between the brick lining and the casing was filled with sand. Below the brick lining was a perforated conical iron bosh. This bosh extended 2 feet 1 inch below the brick lining. Its internal diameter at the bottom was 5 feet. The perforations were used in breaking up the ash bed when clinkers formed. Below the bosh was a revolving ash table, of greater diameter than the bottom of the bosh. The ash, after descending through the bosh to the revolving table, was discharged into the ash pit.

If the uniform discharge of the ash was in any way prevented, so that the ash bed tended to become thicker on one side than on the other, bars could be inserted just above the ash table, through apertures in the ash-pit casing, to cause a more rapid fall of the ash on that side and a consequent equalization in the depth of the ash bed.

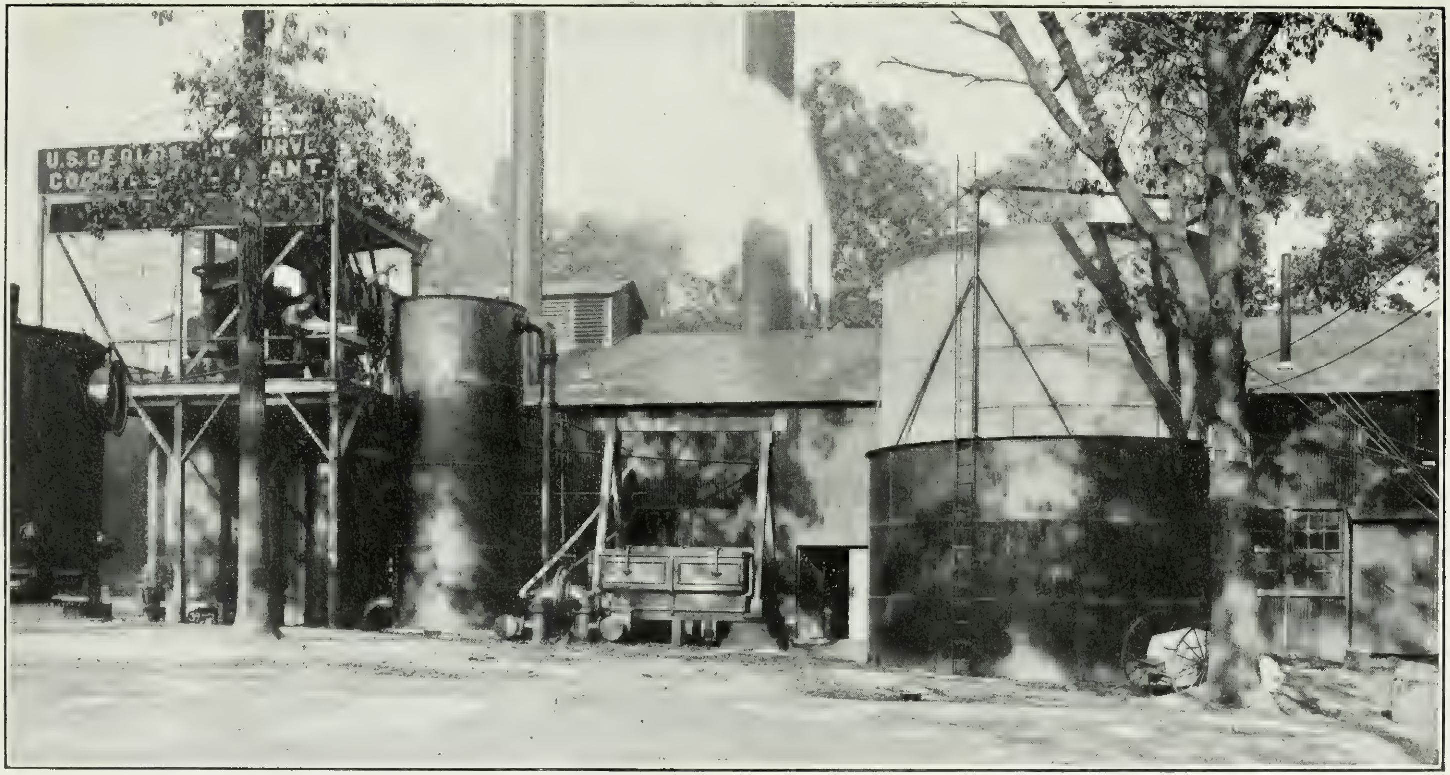
As shown in Plate III*A*, numerous sight holes were made from 5 to 6 feet above the ground, to permit frequent inspection of the conditions within the producer during operation.

The blast pipe passed through the revolving ash table and the bosh. This pipe was 7 inches in internal diameter where it entered the ash pit, but in passing through the ash table it enlarged to 10 inches. Its upper end was covered by a hood to assist in the uniform distribution of the blast. The connection of this blast pipe to the economizer (where the air is preheated) is shown in figures 3 and 4. It will be noted that in this installation two producers and two economizers were connected to a single scrubber.

The blast for the producer was furnished by a steam-jet blower, the steam being drawn from the boilers that were part of the equipment of the testing plant. Figure 3 shows the connection of this steam line to the blast pipe.

Coal hopper and feeding devices.—Above the producer proper, as shown in Plate III*A*, were the coal hopper and feeding devices. These auxiliaries to the producer are described in the manufacturer's catalogue as follows:

> The Bildt automatic feed continuously delivers the coal in a shower from the deflecting surfaces of a constantly rotating distributer. It has a storage magazine, requiring filling at longer intervals than in ordinary charging. The apparatus consists of a receiving hopper surmounting the main storage magazine, communication



PRODUCER-GAS PLANT AT ST. LOUIS.

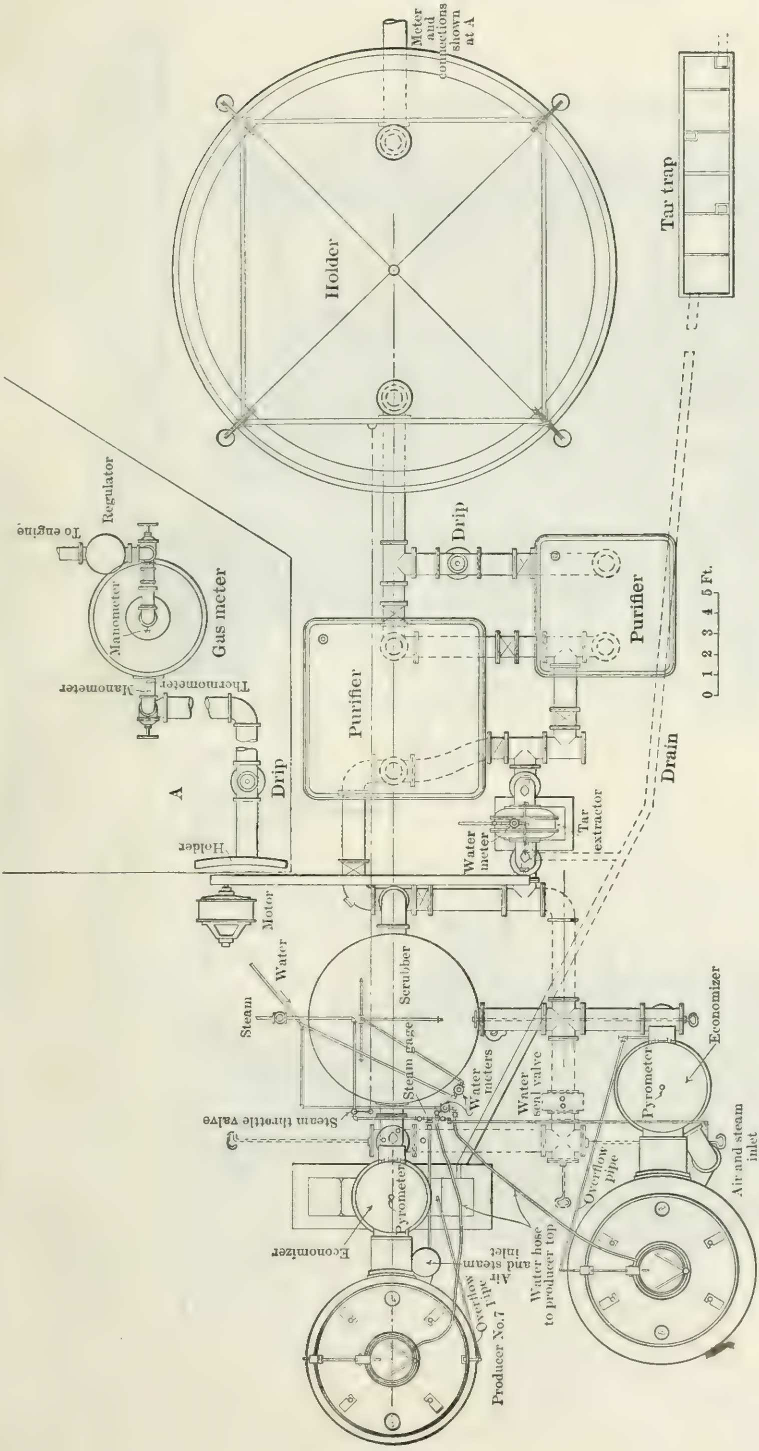


FIGURE 3.—General plan of producer-gas plant at St. Louis.

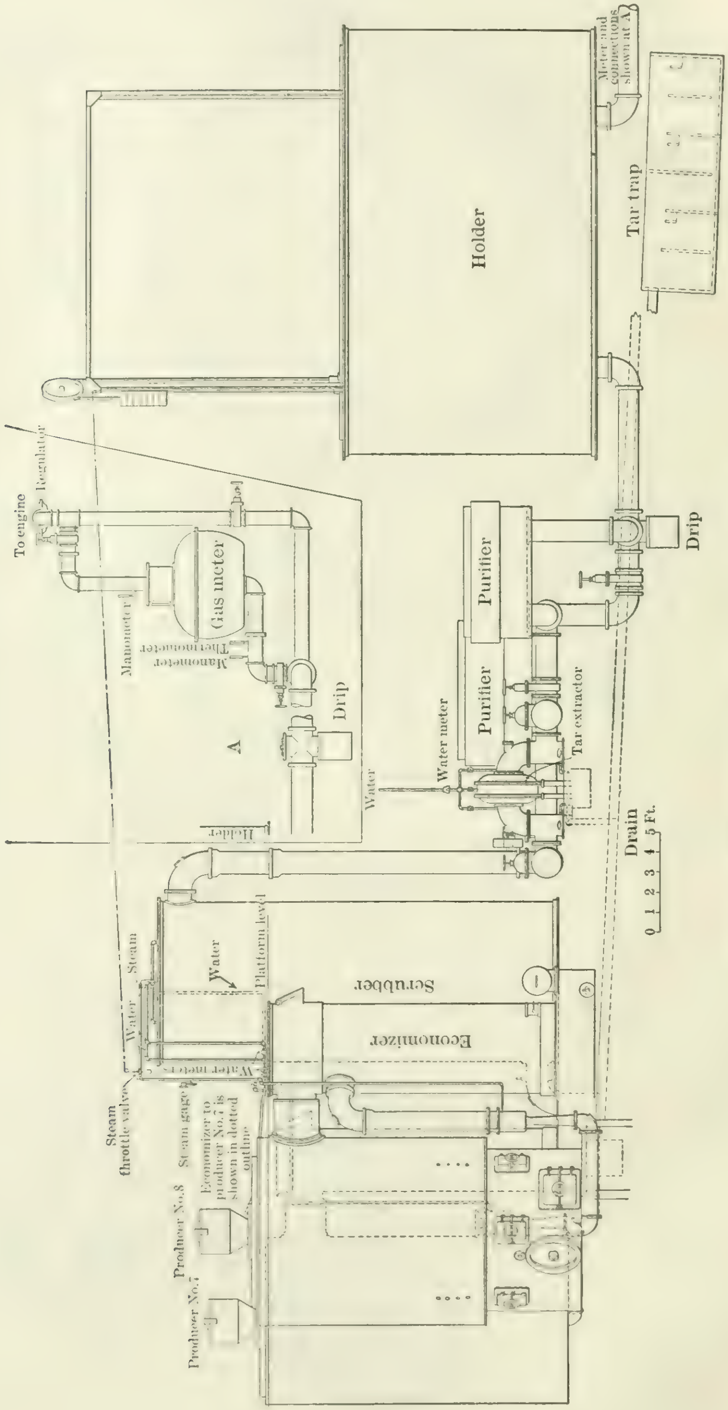
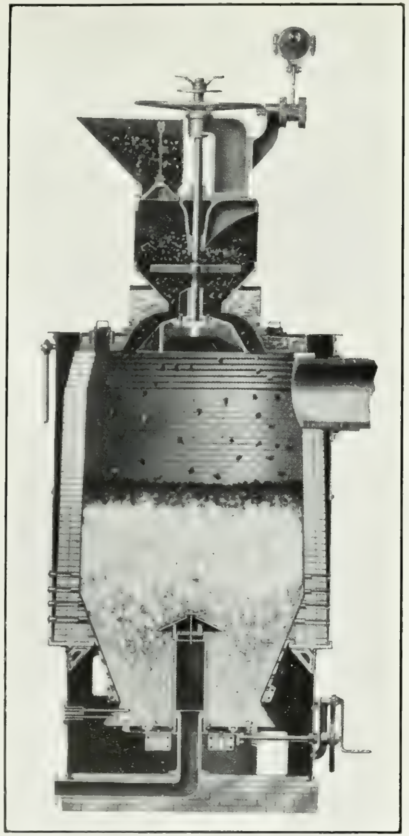
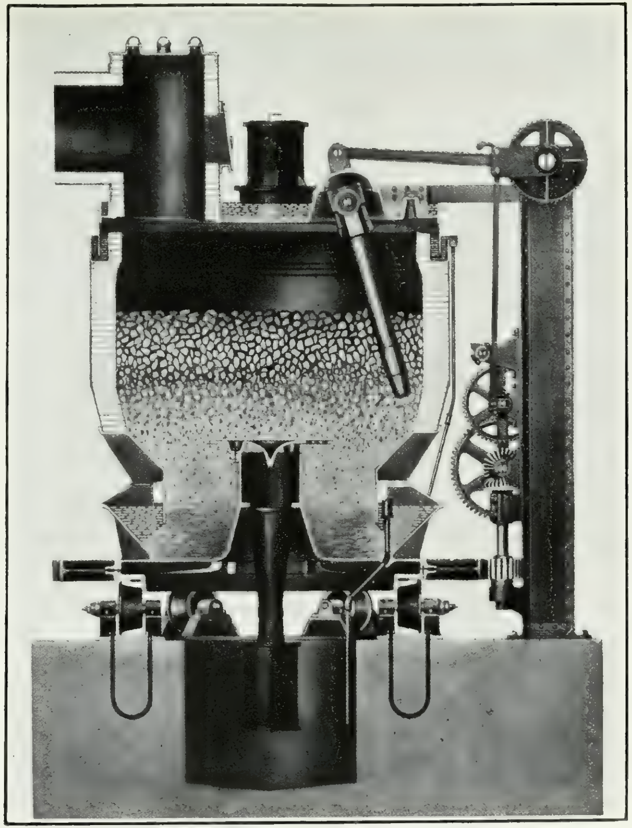


FIGURE 4.—General elevation of producer-gas plant at St. Louis.



A. SECTIONAL VIEW OF GAS PRODUCER WITH ROTATIVE TABLE AND CONTINUOUS AUTOMATIC FEED.



B. SECTIONAL VIEW OF MECHANICALLY STIRRED GAS PRODUCER.

between the two being regulated by a bell valve or by a horizontal rotating register or gate operated by a lever.

Below the main magazine is suspended the distributer plate, its inclosing shield or hood, as well as the inverted conical base of the magazine, being water cooled. The influence of the cooling water and the location of the plate above the gaseous current is to retard caking of the coal. The distributer plate is supported by a steel shaft passing upward through the storage cylinder and suitably guided as shown. At the upper end of the shaft, above the supporting bracket, a worm wheel and worm impart rotation to the distributer shaft. The handwheel nut upon the threaded end of the axis gives a means of adjusting the distance between the distributer plate and the coal reservoir. By such adjustment, and further by variable speed (one revolution in one and one-half to six minutes) secured through a step-cone pulley, the rate of coal discharge is readily controlled. Instead of belting, the worm may be driven by fixing on the countershaft an eccentric, the rod of which, extending to the axis of the worm, carries a pawl engaging a ratchet wheel on the worm shaft. The shaft has bolted to it within the magazine a bar for leveling the coal.

In the sides of the magazine are holes for insertion of a rod, or for inspection when necessary. The lower lip of the dome inclosing the distributer plate slips over the flange or rib rising from the inner edge of the top plate, the joint thus formed being sealed by the water lute as shown. The apparatus, as a whole, may be readily lifted from the top plate, and therefore is easily accessible and facilitates entrance to the producer when desired.

In operating, while still sufficient coal remains in the main magazine to retard escape of gas, and with the receiving hopper full, the coal is allowed to enter the storage compartment. If desired, the opening may again be closed and the operation repeated, or in the first instance the full capacity of the magazine may be drawn from an overhead bin.

A number of these devices have been installed on both hard and soft coal producers, several large plants being so equipped. Such feeds are best adapted to uniformly sized fuel and not to run-of-mine coal. They also require less attention with hard than with soft coals. With coals that cake, especially if there is much fine material, fuel will adhere to the distributer and require scraping off or cleaning by suitable attachment.

The economizer.—The gas left the producer through a 22-inch pipe, as shown in figure 4, and passed through the economizer, which consisted of an iron casing 3 feet in internal diameter and 16 feet 6 inches high, containing six 7-inch tubes. The gas coming from the producer entered a chamber at the top of the economizer and then passed downward through the tubes to a water-sealed chamber or wash box at the base. Connected to this chamber were a tar drip and water overflow, as shown in figures 3 and 4. After passing into this chamber the gas went through a 12-inch pipe directly into the bottom of the scrubber.

The air for the blast entered the economizer through slides near the bottom of the casing and passed upward, surrounding the tubes and absorbing the heat from the hot gas passing downward through them. The heated air left the economizer through the 12-inch opening near the top and passed into the blast pipe, as shown in figure 4.

Scrubber and tar extractor.—The scrubber, an iron cylinder 8 feet in diameter and 20 feet in height, was filled with gas-house coke, which was constantly flushed with water during the operation of the plant. In passing through the scrubber the gas was partly cleansed before entering the tar extractor. The tar extractor in outward appearance resembled a centrifugal pump. As the gas went through the extractor the tar passed down through the tar drips to a water-sealed pit, from which it was easily removed. A liberal supply of water was used during this part of the process of purification. The speed of rotation of the fan in the tar extractor was of vital importance, and any deviation from the proper speed (1,500 revolutions per minute in the plant under consideration), particularly a reduction, seriously affected the successful working of the extractor. The fan in the extractor was driven by a 10-horsepower motor.

Purifier and gas holder.—From the tar extractor the gas passed to the purifier, an iron box 8 feet square and 3 feet 3 inches high. This box was divided into compartments by wooden lattice frames, and was filled with oxidized iron filings and shavings for removing the sulphur from the gas.

Before reaching the holder the gas passed another tar drip. The holder was 20 feet in diameter, 13 feet high, and had a capacity of 4,000 cubic feet. Between the holder and the gas meter on the pipe line leading to the engine was a final tar drip for the removal of any traces of tar or moisture that might have escaped the preceding drips and extractors.

Engine and generator.—After going through a meter having a capacity of 30,000 cubic feet per hour, the gas was delivered to a three-cylinder vertical Westinghouse gas engine. On the pipe line leading from the meter to the engine was a special gas regulator installed in connection with the engine.

The cylinders of the engine were 19 inches in diameter and the length of stroke was 22 inches. The engine made 200 revolutions per minute and was rated at 235-brake horsepower when using producer gas. It was belted to a 6-pole, 175-kilowatt Westinghouse direct-current generator. The load on the generator was controlled and the energy developed was dissipated by a water rheostat constructed especially for the purpose.

FIELD OF THE PRESSURE PRODUCER.

Pressure producers of the type described above were devised to meet the demand for the concentration of power in fairly large units instead of the separate operation of a large number of installations of small power capacity. As indicated in the description, these producers develop their gas under a slight pressure due to the introduction of the air and steam blasts, and the gas is stored in holders until required by the engine. As the generation of the gas does not depend on the suction stroke of the engine, tar and other impurities may be removed from it by suitable devices, and hence the use of bituminous coal, lignite, and peat is possible. Attention should be called to the fact that the pressure in the top of the gas generator does not bear any close relation to the steam pressure carried by the auxilliary boiler; that is, although the boiler pressure may be 60 or 80 pounds, the pressure in the top of the gas generator does not exceed a few inches of water, owing to the great reduction in pressure effected by the passage of steam through the nozzle of the blower at the entrance to the generator.

MODIFICATIONS OF DESIGNS.

Various details of design are modified by different manufacturers. Some of these changes are made simply to satisfy the requirements necessary to obtain a patent; others are made with the idea that they are decided improvements. For example, some of the pressure installations show totally different construction of the fuel-charging apparatus, others introduce the air and steam through a series of blast pipes arranged around the circumference of the producer, and others introduce the air and steam through tuyeres. The economizer, which is primarily nothing but an air preheater, is regarded by some manufacturers as absolutely essential, whereas others go so far as to discard it entirely. Climatic conditions undoubtedly have something to do with the necessity for this portion of the plant.

The range of methods employed for cleaning the gas in the scrubber has been discussed in some detail in the description of the suction-producer plant. In the Survey investigations it was found that ordinary red brick loosely arranged in the scrubber proved fully as satisfactory as coke.

The use of mechanical tar extractors causes a considerable loss in the heat value of the gas produced, and consequently lowers the efficiency of the plant. This loss, however, is offset at some plants by selling the tar for various commercial purposes. At many plants, however, the tar extracted is not only a dead loss but may be a burden owing to the trouble involved in removing it from the premises. Some plants are designed to use this by-product in the boiler furnaces to generate the steam required for the producer.

Purifiers for removing the sulphur from the gas are still the subject of lively discussion. There is no doubt that a certain amount of sulphur can be removed by such devices, but at the St. Louis testing station the regular purifier installed with the plant became saturated with sulphur after a run of only six or eight hours with coals containing not over 2 per cent sulphur. This fact completely destroyed the value of the device in connection with the tests at that station, as most of the fuels used contained relatively high percentages of sulphur (more than 8 per cent in one fuel).

A gas holder is also regarded as entirely unnecessary by many. Plants of several types are manufactured without such holders and are proving eminently satisfactory in commercial practice. In discarding the holder it is of course necessary to introduce automatic devices for controlling the pressure and the supply of gas to the engine.

DOWN-DRAFT PRODUCER PLANTS.

LOSS OF HEAT VALUE WITH THE EXTRACTION OF TAR.

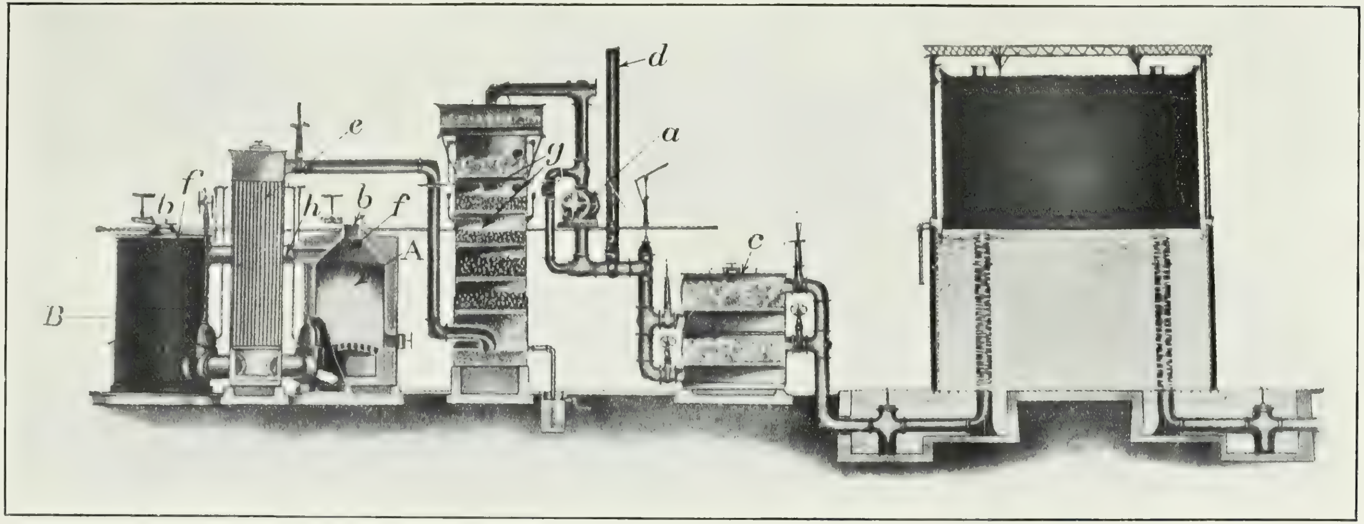
By the mechanical extraction of tar a large part of the heat value of the gas is lost. As already stated, this may not be a serious matter in plants where the sale of the tar for commercial uses brings a good financial return, but in installations where the tar is thrown away the loss is sufficiently serious to warrant the attempt to devise some means of converting this tar into a gas of suitable quality for engine use. Attempts have been made to accomplish this result by manufacturers in this country and abroad, and the success attained has been sufficient to warrant the building of such plants on a commercial basis.

OPERATION OF A TYPICAL PLANT.

General description.—A typical plant of this character manufactured in the United States is shown in Plate IV. This plant consists of two gas generators made of steel shells with fire-brick linings. As in the types previously mentioned, the essential features of this type of plant are the gas generators or producers, the steam generator or boiler, the gas-cleaning apparatus or scrubbers (both wet and dry), the gas holder or receiver, and the necessary auxiliary piping, etc.

In operating the producer plant the gas generators are charged with coke to a height of 3 or more feet above the grates, and lumps of coal about 4 inches in diameter are added on top of the coke to the depth about 6 inches. A wood fire is then kindled on top of this charge. The valves in the pipes at the base of the producers leading to the boiler being open, the exhauster *a* is started and the entire portion of the plant to its left is thus placed under suction. The air for supporting combustion is drawn in through the charging doors shown above the operating floor at *b*, downward through the fuel bed and pipe line into the base of the boiler, up through the boiler tubes and pipe line to the base of the scrubber, and then up through the scrubber into the exhauster. From the exhauster the gas is under pressure and may be sent through the dry scrubber *c* into the gas holder, or by simply opening the valve may be sent through the purge pipe *d*, into the outside air. When starting the fire, smoke and impure gas are diverted through the purge pipe until such time as the test flame shows the gas is suitable for turning into the holder.

After the coke has become incandescent and the fire in the upper portion of the fuel bed well established, green fuel is added through the charging doors *b* as the condition of the fire and the quality of the gas require.



SECTIONAL VIEW OF DOWN-DRAFT GAS-PRODUCER PLANT.

The steam required by the plant is generated in the tubular boiler *e* by the heat of the gases as they pass from the generator to the scrubber. Sufficient heat is furnished in this manner to supply steam at 60 or 80 pounds pressure in the average plant of this type, although occasionally it is found best to install an auxiliary boiler. The steam which enters the producer above the fuel bed at the point *f* mingles with the air entering at *b* and the mixture passes down through the fuel bed, as previously outlined.

The gas is cleaned by the coke scrubber, although in this particular type of plant the scrubber is fitted with partitions or shelves, upon which the coke is placed. The water spray which meets the ascending gas currents is shown at *g*. The upper portion of this scrubber is generally filled with excelsior, thus making a dry scrubber which removes considerable moisture from the gas besides impurities. The additional dry scrubber, shown at *c*, is also filled with excelsior, and consists of two chambers, with valve connections so arranged that either chamber may be by-passed for cleaning.

Conversion of tarry vapors into fixed gases.—By this down-draft process the hydrocarbon compounds and volatile material distilled from the green coal in the top of the fuel bed are drawn into the incandescent zone, where the tarry material is to a certain extent converted into a fixed gas. The completeness of the conversion is determined by the coal used, the conditions of the fuel bed, and the method of operating. Sometimes the process is exceedingly satisfactory and the tarry products are practically all transformed into a good grade of gas; at other times a portion of this material is transformed into gas and a portion is burned in the incandescent zone. One of the criticisms of the system is that at some plants much lampblack is produced. Although this may cause no serious results so far as the operation of the engine is concerned, yet lampblack is a disagreeable substance to handle in any quantity and tends to collect in every nook and crevice. If it is not properly removed when coals containing a high percentage of sulphur are used there is a possibility of a weak solution of sulphuric acid forming in certain portions of the plant and gradually eating away any iron or steel with which it may come in contact.

Composition of the gas.—A gas produced under the normal working conditions, with the air and steam mixture admitted above the fuel bed, shows a heat value of about 110 B. t. u. per cubic foot and the following composition:

Composition of a typical down-draft producer gas.	Per cent by volume.
Carbon dioxide (CO_2)	9.23
Oxygen (O_2)	.16
Ethylene (C_2H_4)	.04
Carbon monoxide (CO)	17.53
Hydrogen (H_2)	11.85
Methane (CH_4)	1.08
Nitrogen (N_2)	60.11
	100.00

"Shooting" the fuel bed.—After operating this plant for a few hours by the method described, the fuel bed in each of the generators gradually becomes clogged with tarry matter, soot, dust, ash, etc., and the suction required of the exhauster becomes excessive. If the plant is clean this suction amounts to possibly 5 or 6 inches of water, and gradually increases as the fuel bed becomes clogged. In the majority of plants it is not deemed wise to allow the suction to exceed about 20 inches of water, although there are some plants in daily operation in which 30 inches are carried without difficulty. When this suction becomes excessive it is necessary to clean the fuel bed. This cleaning, which must be done without stopping the plant, is carried on as follows:

Suppose the fuel bed in the generator marked A (Pl. IV) requires cleaning. The charging doors *b*, *b* are closed, then the valve connecting the base of the producer A to the boiler is also closed by means of a wheel manipulated from the operating floor, and the steam entering the top of the producer is cut off and steam at full pressure, namely, 60 to 100 pounds, is discharged into the base of the producer just below the grate. This high-pressure steam rushing through the fuel bed tends to dispel the tar, soot, dirt, ash, and other foreign material. The process is called "shooting." During the process the current through the fuel bed is, of course, reversed; that is, made to flow upward instead of downward. In the shooting a jet of live steam is turned upon an incandescent fuel bed, and a water gas is formed which is quite different from the gas produced during the down-draft operation of the plant. The heat value of this gas averages about 200 B. t. u. per cubic foot instead of a little over 100 B. t. u., which is the heat value of the gas normally made by the producer. During the process of shaking up and cleaning the fuel bed the water gas is passed up through the fuel bed into the top of the generator A; through the by-pass pipe behind the boiler, shown at *h*; down through the fuel bed of the generator B, and then on through the boiler and scrubber to the exhauster, as in the normal working of the plant. The method of cleaning generator B is the same, except, of course, that the operation of the two generators is in reverse order.

UTILIZATION OF WATER GAS.

The gas produced during the cleaning process, high in hydrogen and of relatively high fuel value, differs so materially from the gas regularly made that many operators of down-draft plants find it inadvisable to mix the two gases, and provide two gasometers, one for the regular producer gas, or air gas, as it is sometimes called, the other for the gas generated during the shooting process, which is generally termed water gas. The discharge of these two types of gas to their respective gasometers is controlled by the operator on the charging floor. The number of times a bed should be shot during the day depends largely upon the character of the fuel used, the demands on the plant, and the methods of manipulation. It is not deemed desirable to utilize the water gas in some plants used only for power purposes, and the gas is discharged into the atmosphere through the purge pipe. In certain plants with high-grade fuels and proper manipulation it is necessary to shoot the bed only two or three times a day. As the period required for the operation is not over a minute or two, the resultant loss from the discharge of gas through the purge pipe amounts to very little. In other plants where producer gas is used for heating, annealing, tempering, forge work, etc., in addition to its use for the development of power, it is advisable to generate as much of the higher heat-value water gas as possible. To this end, the bed is shot as often as may be done without chilling the incandescent zone below an efficient temperature.

One company operating gas engines and also various heating processes has large gasometers for each of the two types of gas and mixes them in the proportions which experience has shown to be the most satisfactory. For certain forms of heating, the water gas is used directly; in other processes the two gases may be mixed in the ratio of 1 to 2, or half and half, etc. For engine work the company uses about 1 part water gas to 5 parts air gas, and obtains a mixture with a heat value of about 135 B. t. u. per cubic foot. Another company developing power only, utilizes the gas, whether it be air gas or water gas, in the engines and reports excellent results.

The operating floor of a typical down-draft producer plant which develops power to run a street railway by means of gas engines and electric generators is shown in Plate V*A*. Plate V*B* presents a view of the engine room of a power installation consisting of twin-tandem, horizontal double-acting engine units of 800 horsepower each, supplied with gas from down-draft producers.

A SINGLE-GENERATOR DOWN-DRAFT PLANT.

To meet the demand for plants of the down-draft type in units below 500 horsepower, a single-generator system has been devised. In this type of installation the boiler with its high-pressure steam used in the double-generator plant is replaced by an economizer (preheater) and steam generator, shown at *a* in Plate VI. The main features of such a plant, with the exception noted, are practically the same as those of a double-generator plant. As shown in the plate, water trickles down the side of the pipe *b*, which carries the hot gas direct from the gas generator. This water coming in contact with the hot pipe is vaporized, and the air entering the base of the preheater and passing up around the hot pipes carrying the gas is not only warmed, but is also charged with steam by the time it enters the producer through the pipe *c*.

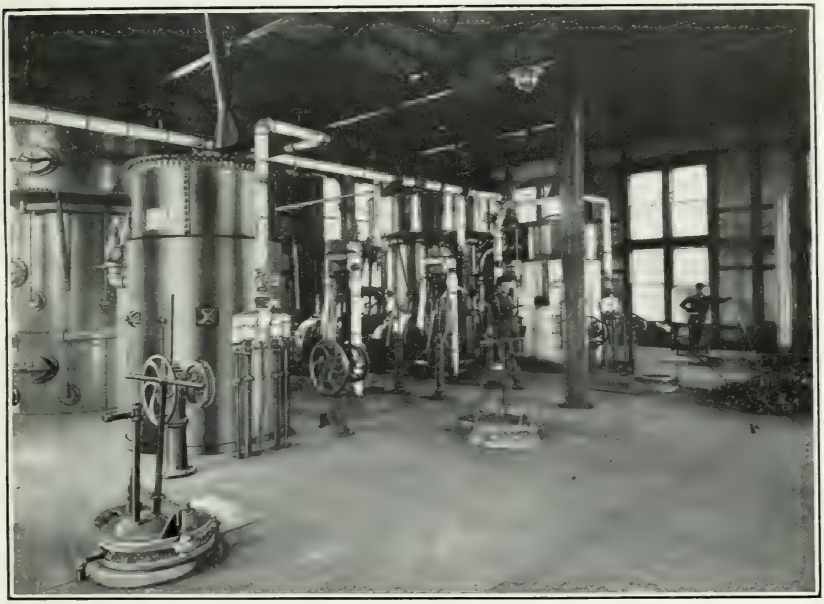
Inasmuch as there is no steam at high pressure, the shooting of the fuel bed is done by compressed gas. A certain portion of the gas generated by the system is compressed and stored in tanks to be available for shooting whenever the condition of the fuel bed requires it. Evidently, as no steam is used for shooting, no water gas is generated by this system.

Fuel tests with a 150-horsepower plant of this type were conducted by the Geological Survey at the Pittsburg station for two years. Details of this plant are presented in figures 214 and 215 (pp. 315, 316).

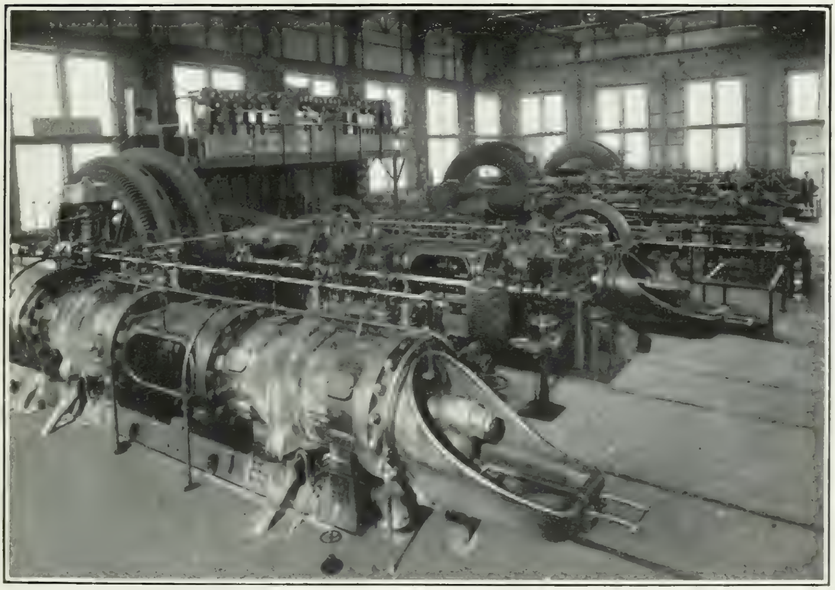
SPECIAL PRODUCER-GAS ENGINE CONDITIONS.

In order to make producer gas suitable for use in an engine the gas, as already stated, must be thoroughly scrubbed and cleaned and sent to the engine at a low temperature. Lowering the temperature increases the density of the gas, so that a given volume contains a larger number of heat units and can develop more power in the engine. Another advantage in sending cold gas to the engine is that it prevents condensation of tar or water vapors in the cylinders. This advantage is probably a minor one, since the engine cylinders are usually kept hot enough to prevent any possibility of such condensation, even if the gas be delivered at a relatively high temperature.

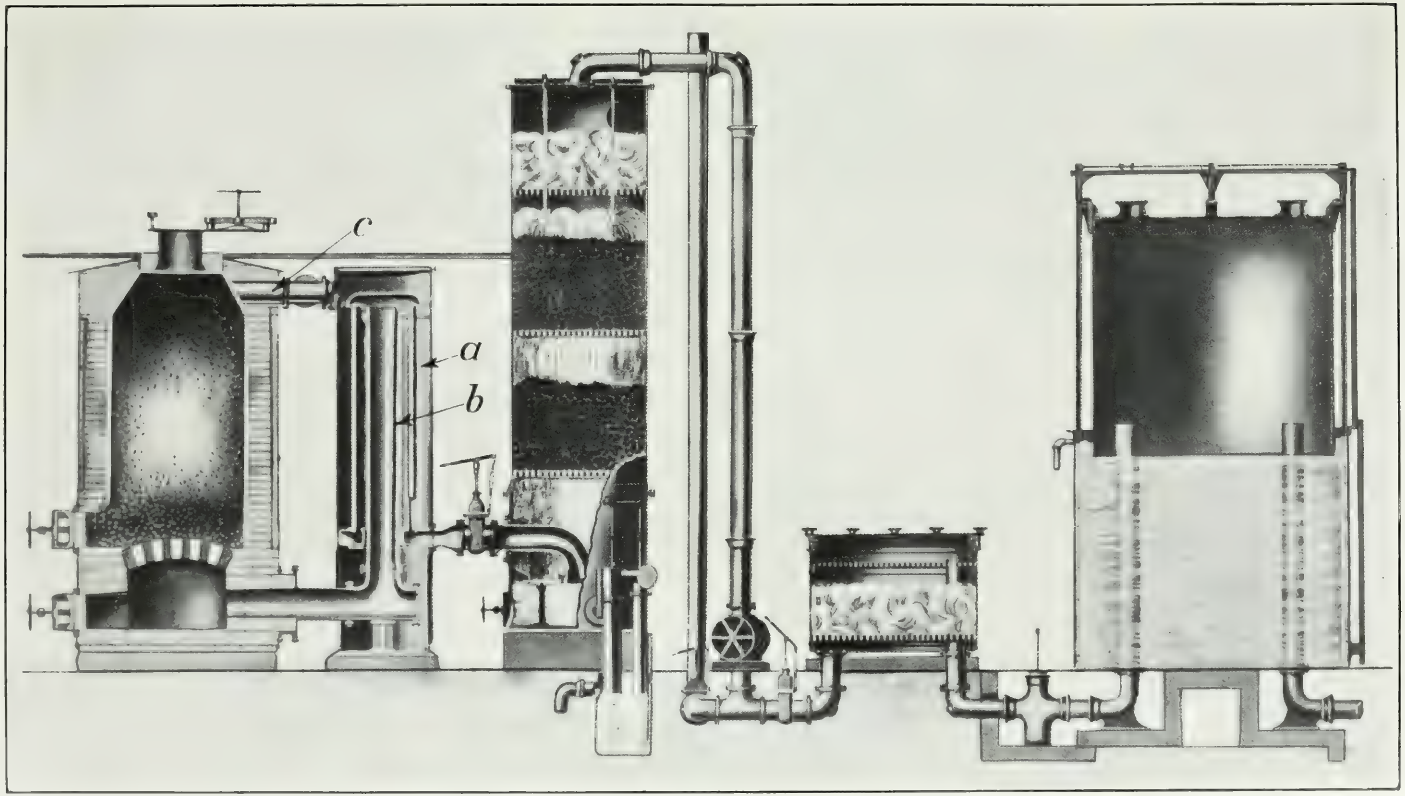
It is necessary that the compression in the engine cylinder be properly adjusted for the gas which is to be used. Owing to the varying composition of producer gas, some mixtures have a far greater tendency to ignite at a low temperature than others. Consequently it is imperative that the compression of the gas be checked before the temperature produced by compression becomes high enough to cause ignition. It should be stated that in one type of engine (Diesel) the gas is ignited by the temperature produced by compression, but this type of engine is not operated with producer gas. In engines using producer gas the gas is usually ignited by means of electric igniters so regulated and adjusted that the time of ignition can be accurately predetermined by the operator of the engine. If ignition is allowed to take place at any other time than that fixed by the mechanical working of the igniter, it is likely to cause serious inconvenience, a reduction of power and loud reports that are very objectionable in thickly settled communities. So much trouble may be caused by premature ignition that great care has to be exercised in the design and construction of engines to prevent it. Experience has demonstrated that the compression which is well adapted to certain gases can not be used safely with others. For example, compressions of about 65 to 75 pounds per square inch seem to



A. OPERATING FLOOR OF DOWN-DRAFT GAS-PRODUCER PLANT.



B. TWIN TANDEM 800-HORSEPOWER GAS ENGINES.



SECTIONAL VIEW OF SINGLE-GENERATOR, DOWN-DRAFT GAS-PRODUCER PLANT.

be best adapted to gas from gasoline, but if alcohol is used in place of gasoline the most advantageous results are not obtained until the compression has been increased to approximately 180 pounds per square inch. Pressures ranging from 120 to 200 pounds per square inch have been used more or less successfully in engines driven by producer gas; but the average pressure employed is about 140 pounds.

It is equally true that a gas of constant quality from a certain coal will operate perfectly in an engine with a certain compression and cause serious preignitions in an engine having the same compression, but of another design. Without going into this question in detail it is sufficient to call attention to the fact that the proper design of the combustion chamber and the proper methods of jacketing an engine for operation on producer gas require thoughtful study and careful investigation of details, backed by a liberal experience.

Owing to the high pressures that prevail in the cylinder of an engine using producer gas, it is exceedingly important that in the design of the engine all parts be made strong enough to resist rupture and to insure stable and regular operation.

PRODUCER GAS FOR METALLURGICAL AND HEATING PURPOSES.

APPLICATION IN THE IRON AND STEEL INDUSTRY.

Producer gas has for years been extensively used in various types of furnaces in the manufacture of iron and steel. This use has become more and more general during the last few years. In districts where the steel mills have had an abundant supply of natural gas no necessity for a substitute has been felt and no incentive for economizing the fuel supply has existed. The supply of natural gas, however, is by no means unlimited—in some places it has failed altogether—and the time when it will no longer be available in large quantities is near. Large users of this remarkable natural resource have had to recognize these conditions and to hold themselves in readiness to use artificial gas when the supply of natural gas becomes inadequate. The solution of the problem is found in the gas producer, and at the present time there are within the natural-gas regions large installations of gas producers used for the operation of open-hearth furnaces.

In the manufacture of producer gas for metallurgical processes the gas goes to the furnace directly from the producer without any cooling or cleaning. It therefore enters the furnace highly heated, carrying with it all volatile hydrocarbons and tarry matter, as gases or vapors, and these add much to the heat value of the gas. The simplicity of the gas-producer equipment required where cleaning of the gas is not essential is shown clearly in the plan and elevation, figure 5. The gas passes directly from the producers A, through the pipes B, to the open-hearth building.

OTHER APPLICATIONS AS A FUEL.

The abundance of natural gas and the multiplicity of uses to which it has been applied have led to a much greater appreciation of the advantages of gaseous fuel, and have helped to emphasize the value of the gas producer. During the past few years there has been great development in the utilization of producer gas not only for power purposes and in the manufacture of iron and steel, but in other industries as well.

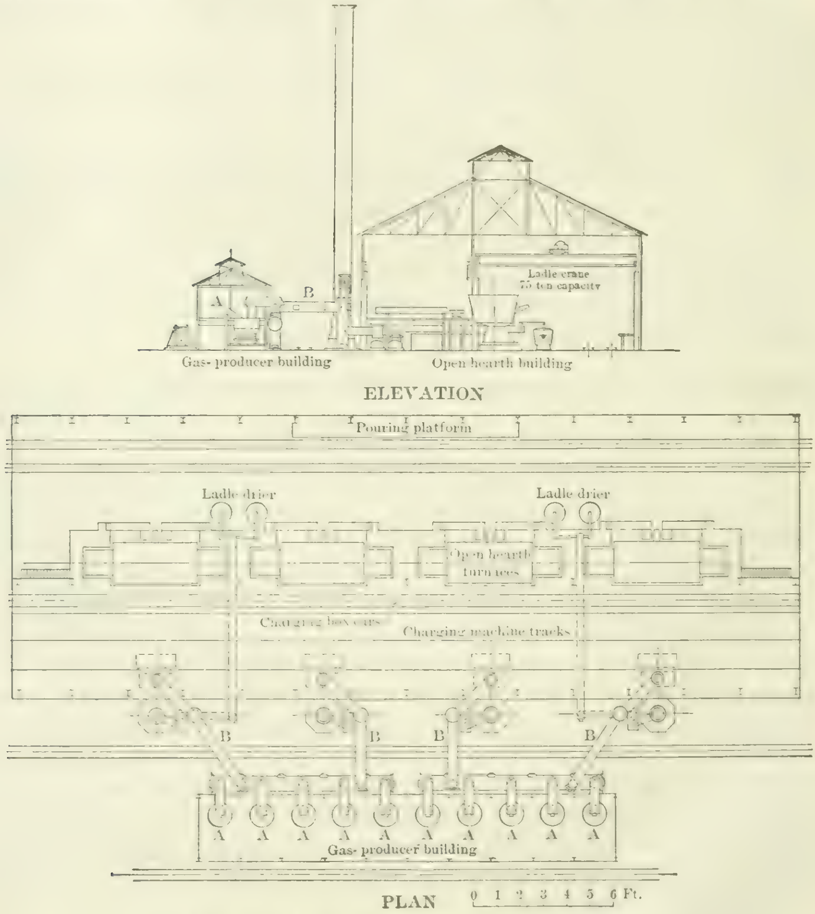


FIGURE 5.—Plan and elevation of a metallurgical producer-gas plant.

Among the uses to which producer-gas fuel has been put are annealing, japanning, enameling, soldering, brazing, galvanizing, drying, evaporating, tempering, casehardening, type casting, yarn singeing, heating molds, wash kettles, ladles, stoves, baker's ovens, and cooking. It has also been used quite extensively in brick, lime, and cement kilns, and in various types of ore-roasting furnaces.

In using producer gas as a fuel one should remember that the heat value of the gas is low compared to that of the other gases used for similar purposes, with the exception of blast-furnace gas. Natural gas has an approximate average heat value of 1,000 B. t. u. per cubic foot; the heat value of artificial or ordinary city gas is about 650 B. t. u. per cubic foot; whereas the heat value of producer gas ranges from 100 to 275 B. t. u. per cubic foot, according to the method of production. This relatively low heat value must be taken into account when considering the method of application. In spite of its low heat value producer gas is usually cheaper for work requiring relatively large quantities of gas than any other fuel, with the possible exception of natural gas sold at a low price.

The introduction of producer-gas fuel for all types of service necessarily requires at the present time a certain amount of careful engineering promotion, due to the uncertainty that exists regarding its successful use in fields in which natural or artificial gas or even solid fuels have been in vogue for years. In one extensive installation in which producer gas is distributed over a large area from one central plant, perfect confidence has been established in its reliability for continuous service and in the uniformity of the heat value of the gas. However, there seems to exist in the minds of the manufacturers who would like to utilize it some uncertainty regarding methods of application that will insure the uniform output of their product with the same guaranteed quality as their present output prepared with a gas of higher heat value. It has been necessary, therefore, to erect at the central plant different types of furnaces, ovens, forges, etc., and to make definite applications of producer gas to the various industries in order to demonstrate conclusively the ease with which this fuel can be applied to the various mechanical trades. Much of this pioneer work has now been accomplished and has resulted in the use of producer gas as a fuel in a large variety of mechanical operations.

ADVANTAGES OF PRODUCER-GAS FUEL.

In many possible applications of producer gas as a fuel there seems to be little if any gain over direct firing with coal. Opinions differ regarding this point, many claiming that there is always a considerable saving in favor of producer gas. The difference either way is probably small, but other considerations are frequently of such importance as to give producer gas a great advantage. Under conditions requiring uniformity of temperature for continued periods, or variations in temperature at positive intervals, the ease with which the supply of producer gas can be regulated insures results that would be entirely impossible with solid fuel. Producer gas may also be employed with comparative ease as a reducing agent.

Under the simple conditions required for boiler heating, it is questionable whether any advantage is to be obtained by the use of producer gas except, possibly, where low-grade fuels are burned. There are many fuels that can be utilized to advantage in the gas producer that can not be employed in direct steam-boiler firing. An incidental advantage which may be important in urban communities is the reduction of smoke resulting from the use of the producer.

In large plants there may be considerable advantage in using producer gas in place of coal, due to the fact that the gas can be so easily piped from the producers to different parts of a plant. This advantage is particularly marked where it is inconvenient to distribute coal to several boiler installations, and may result in a considerable financial saving. Some writers on the subject are enthusiastic enough to believe that the manufacture of producer gas by large central plants at the mines, and the distribution of this gas through pipe systems over a broad area, will become general within the next few years.

In lime burning it is claimed that greater economy is obtained with producer gas than with coal, and that the output of a plant is considerably increased. The heat produced by the gas is readily controlled, and it is claimed that the flames from burning gas are ideal for the process. Owing to the absence of ash and clinker a much cleaner and purer product is produced, and the labor required is reported as considerably less than that demanded with solid fuel. Reduction in the repair bills is also claimed, as the life of the kilns is longer and the necessary repairs are less than when solid fuel is used.

Although producer gas has been satisfactorily used for ore roasting, the development in this direction has been slow, owing to the fact that there is a natural hesitancy about adopting new methods.

In forge work the substitution of producer gas for oil, city gas, and natural gas is developing, although special care is necessary regarding the methods of application. Producer gas is economical and does away with the dirt and smoke so prevalent in forge work when coal is used.

The substitution of producer gas in place of coal for cement burning seems to offer an attractive field. Although this substitution has been made in only a few instances and has not become general, it is attracting the attention of manufacturers. It is claimed that excellent economy is obtained, that a high-grade, uniform clinker is produced, and that the ease of control, the simplicity of the equipment, and the low cost of the installation and up-keep make producer gas an ideal substitute for coal. In discussing this question cement manufacturers have expressed the opinion that the application of producer gas to clinker burning presents many of the advantages named, but at the same time they state that, as far as their information goes concerning installations of this process, there has been difficulty in getting as large an output as had previously been obtained with coal.

GAS-PRODUCER FUELS.

FUELS USED IN THE SUCTION PRODUCER.

The peculiar characteristics of the suction-producer plant practically limit fuels for this type of installation to those containing little or no tar. Hence anthracite and semianthracite coal, coke, and charcoal are the principal fuels utilized. The standard types of suction producer are designed with reference to using these fuels in what is commonly known as pea size. The fuel size usually designated in specifications for such plants is No. 1 pea. Larger sizes can be utilized to good advantage in many cases, but as a rule they are more expensive. If very small coal is to be used, such as rice, barley, fine screenings, or coke breeze, special producers are usually required.

CHARCOAL.

From the standpoint of simplicity of operation charcoal is an ideal fuel, but its tar content, although small, sometimes causes a little difficulty. On account of its expense, however, charcoal is used in very few plants in the United States. Plants are in operation using this fuel at a cost of $13 a ton and the owners claim that the fuel cost is considerably below what it would be if city gas were used.

ANTHRACITE.

Anthracite is the standard fuel for suction producers in this country, and under certain conditions it is an ideal fuel. There are a great many power plants in daily use that require attention not over two or three hours a day and are as reliable as any steam-engine plant of the same size and far more economical. On the other hand, there are many installations which require attention practically all the time, and even then are frequently shut down. The troubles of these plants are often traceable to serious clinkering which may be due to the behavior of the coal under certain temperature conditions, and may be unavoidable in plants of the ordinary construction. However, in many instances clinkering and a bad condition of the fuel bed are caused by an overload or excessive demands upon the plant. For the most part these overload conditions are undoubtedly due to an overrating of the producer by the manufacturers. This fact has already been recognized by some makers with the result that the guaranteed rating of their plants has been reduced 25 per cent for the same area of fuel bed.

Even with the same working conditions much less difficulty is experienced with one grade of anthracite than with another. It is doubtful, however, whether sufficient study has yet been made to warrant drawing fuel specifications that will guarantee practically no difficulty in producer plants of the suction type.

In handling these suction producers it is necessary to keep the grates free from clinker and ash in order to facilitate the action of the engine in producing the necessary draft, and to keep a clean fire a great many operators rake out considerable partially burned coal. It is the custom in many plants to throw this partially burned material back into the producer. While this practice is satisfactory in some cases, yet with certain kinds of anthracite it facilitates clinkering. As a result the practice has been abandoned in some installations and the partially burned material or coke is saved for use in fire places or kitchen ranges.

Although attention has been called to some of the difficulties encountered in the use of anthracite coal, it must be understood that these troubles are not general. A large proportion of the several hundred plants in the United States now operating on anthracite are giving excellent satisfaction and little or no trouble is experienced with them. An examination of the records of inspection of many of these plants reported in Bulletin 416[a] may prove of interest in this connection.

COKE.

In the United States coke is little used in producer plants of the suction type. It gives much more trouble from clinkering than anthracite and its use necessitates taking a longer time to get the producer into operation in the morning after a standby over night. Coke seems to be used much more generally in Europe than in this country. Some people abroad advocate mixing coke and anthracite for economy. (In England the price of coke is about one-half that of anthracite.) One manufacturer of a suction plant in very general use in Europe advertises "20 horsepower hours for 1 penny" as the cost of power when using coke in a plant made by him. However, on looking up the particular installation reported to be operated at this low cost I was informed by the owner that although coke cost about one-half as much as anthracite, he was compelled to use twice as much of it; consequently the fuel cost is practically equal for both fuels. In actual operation this plant shows a fuel cost averaging about 9 horsepower hours for 1 penny. Under the best conditions it may develop 12 or 14 horsepower hours for 1 penny, but never 20. It is claimed by many operators that the best results with coke are obtained when it is crushed to walnut size.

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[a] Fernald, R. H., Recent development of the producer-gas power plant in the United States, U. S. Geol. Survey Bull. 416. 1909. 82 pp. Reprinted as Bureau of Mines Bull. 9. 1911.

LIGNITE.

Many efforts have been made to develop suction plants which will prove commercially profitable in the use of the tarry fuels, such as bituminous coal, lignite, and peat. Considerable success has been attained both in Europe and the United States with the use of lignite in suction producers. In the States of Texas and Washington several plants ranging in size from 25 to 250 horsepower are operating on lignite. The brown-coal briquet of Germany forms an excellent producer-gas fuel and is in very general use in small suction plants of the double-zone type. In the natural state this brown coal, which corresponds to the lignite of the United States, is undesirable for use in producers unless in good sized pieces similar to those of freshly mined Texas lignite. The plants burning brown coal apparently require no more and perhaps less attention than plants using anthracite.

PEAT.

Up to the present time peat has not been commercially utilized in this country as a fuel for the suction producer, but there is every reason to believe that it will be in the near future. Among the most interesting producer-gas plants in Europe are those burning peat. The application of small peat-burning producer plants for generating power has become general in Europe, although the first plant of this type was installed only five or six years ago. Before it is charged into the producer, air-dried peat, containing about 25 or 30 per cent moisture, is passed through a crusher and broken into pieces 1 to 4 inches in diameter.

The Canadian government has just installed a peat-burning producer-gas plant for experimental researches on local peats. The producer and engine were both imported from Germany, however.

BITUMINOUS COAL.

The operation of the suction producer on bituminous coal has been attempted by nearly all producer-plant manufacturers. In both Europe and this country the demand for small power units to operate on bituminous coal is large. Little success has been attained in this country in meeting this demand, but abroad the leading manufacturers are nearly all working on the problem, and each one has some form of plant which he feels is well adapted to bituminous coal. Limitations are imposed abroad, however, which would not be regarded as practical in this country; that is, special restrictions are placed on the types of fuel that may be used. One manufacturer states that the bituminous coal used in a suction plant of his design must be of good quality, low in ash (8 to 10 per cent as a maximum), and noncaking, and must not contain more than 7 per cent tar. The same idea is expressed by another manufacturer, who says that for other than anthracite he confines his attention to short-flaming, low-ash fuels that do not cake and make little tar. Although I saw several of these suction plants specially designed for bituminous coal, only one was in actual operation. This was a double-zone plant of 250 horsepower supplying gas to a 150-horsepower twin single-acting horizontal engine. It is reported that the fuel used in this plant contains 25 per cent ash and 2 per cent sulphur, and that the high ash content gives no trouble so long as the coal is noncaking. In this installation it is imperative that only coals possessing certain qualities be used. To satisfy these limitations three varieties of coal are often required, mixed in proper proportions. All fine coal is sifted and the dust thrown out to prevent matting. Under similar restrictions it is difficult to see how such plants can meet commercial demands. All suction plants for bituminous coal that were inspected abroad were of the double-zone type.

FUELS USED IN PRESSURE OR DOWN-DRAFT PRODUCERS.

PRACTICALLY ALL FUELS OF COMMERCIAL VALUE AVAILABLE.

The range of fuels which can be used in either the pressure or down-draft plants is much greater than that for the suction plant. All of the fuels mentioned for the suction plant, considered purely for their gas-making qualities, are available for use in these installations. The price is the principal controlling factor, and in most sections of the country practically limits the use of anthracite to comparatively small plants.

A few companies operating pressure and down-draft plants prior to 1904 ventured to use certain well-tried bituminous coals known to be especially free from sulphur and a tendency to cake, and low in both ash and tar-producing compounds. It remained, however, for the Geological Survey to demonstrate the possibility of using in such plants practically all grades of fuels of any commercial value without reference to the proportion of sulphur or tarry compounds that they contain. Several of the poorest grades of bituminous coal showed remarkable efficiency in the gas producer, and lignite and peat were used with great facility, thus opening the way to the introduction of cheap power into large districts that have thus far been commercially unimportant from a lack of such power. Experiments with bone coal have given excellent results, showing an efficiency in the producer equal to that obtained by using good steam coal under boilers. Recent investigations with other low-grade fuels, such as roof-coal slabs, culm, and washery refuse, have also demonstrated the possibility of using such material to advantage in the producer.

RESULTS OF PRODUCER TESTS OF LOW-GRADE FUELS.

The results obtained from some of the low-grade fuels are shown in the following table:

Results of producer tests of high-ash fuels.

	Fuel from—	Variety.	Moisture.	Ash.	Fuel as fired consumed in producer per b. h. p. hour.
			Per cent.	*Per cent.*	*Pounds.*
1	New Mexico	Bituminous, run-of-mine	3.62	19.63	1.10
2	Tennessee	do	3.55	20.57	1.45
3	Iowa	Bituminous	16.69	20.70	1.56
4	Wyoming	do	9.44	20.72	1.70
5	Illinois	Bituminous, slack	12.76	21.52	3.98
6	Wyoming	Bituminous, run-of-mine	8.65	21.73	1.83
7	Illinois	Bituminous, bone	8.67	23.12	2.88
8	Brazil	Bituminous, run-of-mine	10.96	23.44	2.02
9	North Carolina	Peat	13.88	27.78	3.37
10	West Virginia	Bituminous, bone	2.91	28.08	1.26
11	Pennsylvania	Bituminous, washery refuse	2.68	30.35	2.34
12	do	Washery refuse	2.25	31.89	2.76
13	West Virginia	Bituminous, bone	.47	43.74	1.65

With such a wide range of available fuels, and with the supply of anthracite and the better grades of bituminous coal decidedly limited, the types of producers now in use will doubtless be improved and modified so as to adapt them to the low-grade or high-ash fuels. The general situation in Europe is much like that in the United States, the manufacturers for the most part use the better-grade fuels and, in consequence, the poorer fuels are left in the mines. This policy is regarded as a dangerous one, and a great deal of interest is shown in the possible utilization of these low-grade fuels in the gas producer.

Although, as already stated, in the United States bituminous coal has been used in producers supplying gas engines within only a few years, it is also true that for furnace work the gasification of bituminous coal in producers has been carried on much longer. The tarry vapors formed add materially to the heat value of the gas and are consequently of advantage in this type of work. As tar and soot interfere seriously with the operation of the engine, the introduction of cleaning apparatus for power-producer plants has been imperative and has complicated the design and construction of these plants considerably.

Besides the fuels previously mentioned producers have been operated on wood, sawdust, tanbark, straw, hay, corncobs, cornstalks, and even leather scraps, but these fuels, with the possible exception of wood and sawdust, have not come into general use.

EUROPEAN PRACTICE.

During a recent inspection trip in ten European countries I found anthracite, brown-coal briquets, and peat in general use in producer-gas power plants. Bituminous coal is also extensively used, but in the majority of plants only noncaking coals of moderate tar production and low ash content are burned in the producers. One installation of many thousand horsepower used coal taken from mines bought expressly for the purpose of supplying the plant with a good producer coal, but even there only the high-grade coal was utilized and the coal relatively high in ash was left underground.

I found only two instances of the use of high-ash fuels. In one instance, a mixture of culm, roof coal, and washery refuse, reported as averaging 53 per cent ash, was being utilized in an experimental by-product recovery plant which had been in commission about one year. Considerable time was required for adapting the plant for the successful handling of the fuel, but the reports indicated that for the three months previous to my visit little or no difficulty had been experienced.

The other instance was a plant in full operation using roof slabs that gave little indication, on casual inspection, of containing any combustible material. It was claimed that the slabs averaged over 60 per cent ash. At the time of this visit (1908) the producers were not only supplying a number of furnaces with gas but were also operating a 1,000-horsepower and a 250-horsepower engine, and a 500-horsepower engine was being added to the equipment. The plant was reported to be using over 100 tons of this low-grade fuel per day.

CAPACITY OF PRODUCERS.

HORSEPOWER OF PRODUCERS.

It is customary at the present time to designate the capacity of gas producers in terms of horsepower. As is the case with boilers, however, this usage is a misnomer, since there is no such thing as the horsepower of a producer. The expression strictly means the size of producer that will uniformly supply an engine of a given horsepower rating with gas over a considerable period of time; that is, a 250-horsepower gas producer means one that will supply sufficient gas to operate an engine rated at 250-brake horsepower for several consecutive hours under full load.

From the general discussion on gas-producer fuels it will be seen that the quantity of fuel which can be burned in a given gas producer per hour and the quantity of gas which can be generated will vary widely according to the kind of fuel used. This point is perhaps made clearer by figures 6 and 7, which show the rate of burning of a large variety of fuels in a producer of fixed dimensions necessary to develop sufficient gas to operate a 235-brake horsepower engine at full load. A wide difference will be observed in the required rates of fuel consumption between the coals of high heat value (14,000 or more B. t. u. per pound) and those of low heat value (between 7,000 and 8,000 B. t. u. per pound).

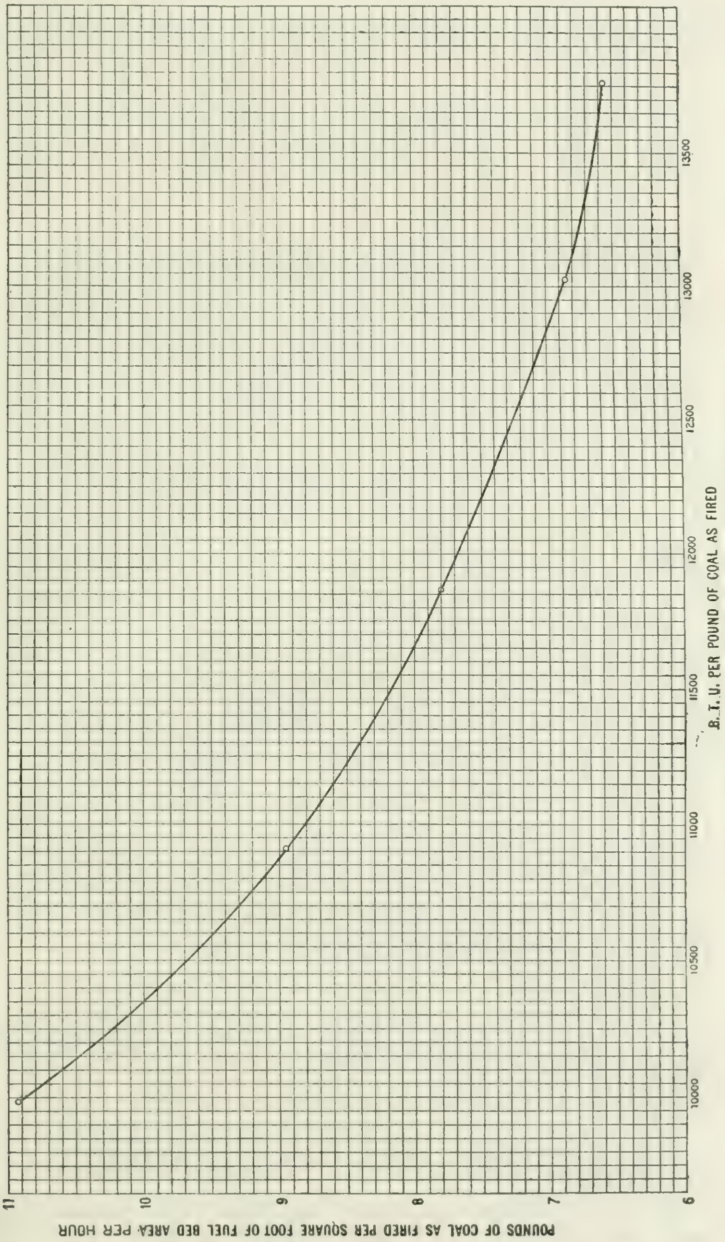

FIGURE 6.—Relation of rate of firing to calorific power of fuel.

Again, it is obvious, from a study of the curve shown in figure 6, that if the rate of burning the high-heat value coals be increased to that which prevails for the low-heat value fuels, the volume of gas generated will be large enough to supply an engine of much more than 235 horsepower. In other words, the producer which would be called a 235-horsepower producer with one fuel might be rated as 300 horsepower with another fuel and 400 horsepower with another.

For metallurgical and furnace purposes in which no engine is employed there is no definite relation between horsepower and producer size. In general, then, a better method is to designate producers by the diameter of the fuel bed and the rate of burning the fuel per square foot of fuel-bed area.

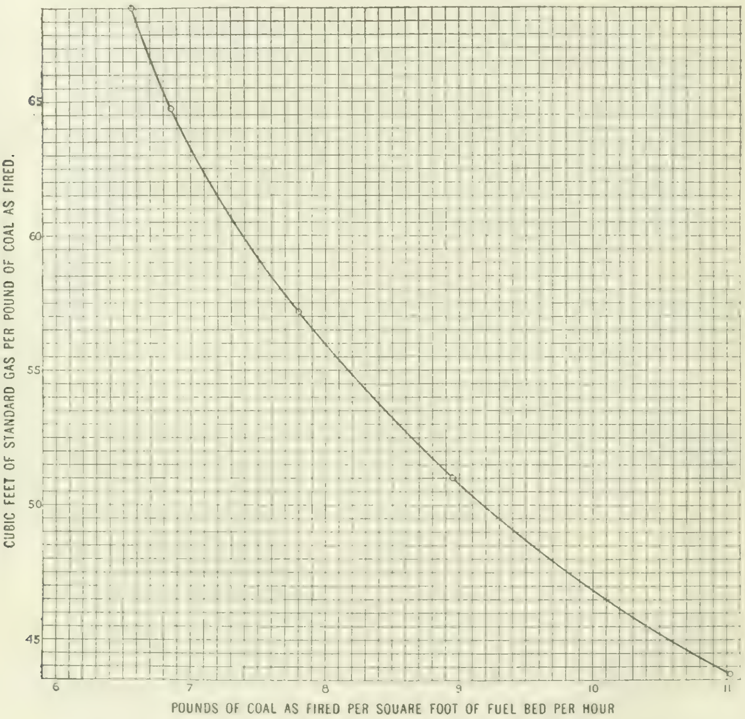

FIGURE 7. Relation of volume of standard gas generated to rate of firing.

RATE OF FUEL CONSUMPTION AND TENDENCY TO OVERRATE CAPACITY.

This rate of fuel consumption is an uncertain factor and has led to much difficulty in designing and in rating producers. Early work in this country followed European practice almost entirely and thereby occasioned a great deal of trouble in properly rating the plants and brought about the ultimate failure of many of them. Under European conditions, in which fuels of a certain grade are specified, high rates of fuel consumption may be obtained. It is not impossible to obtain similar rates under corresponding circumstances in this country, but as these exceptional conditions seldom prevail, it has been found that in general the rate of fuel consumption per square foot of fuel-bed area does not average much over half the amount originally guaranteed by the early manufacturers. This fact has, of course, led to a decided modification in the design and proportions of many plants. Even to-day there is some tendency to overrate producers, especially those of the suction type. Such overrating is not only likely to make trouble in adjusting the purchase price of these plants, but usually results in serious operating difficulties, if the installation is worked at or near its capacity. It has been observed frequently that a given plant using anthracite of good quality will present no operating difficulties when working up to 50 or 75 per cent of the rated capacity of the producer, but if the producer is forced to its full rating for any length of time, clinkering and other troubles are encountered. These are often sufficiently serious to necessitate a reduction in load at a time when such a reduction is most inconvenient.

Although it has been intimated that the rate of burning high-grade coal might be materially increased over that indicated in figure 6, it should not be understood that such an increase is always possible. A great deal depends on the character of the fuel. This is particularly true regarding the nature of the ash. If the ash is highly fusible it may cause such serious trouble from clinker that the rate of fuel consumption will be decidedly restricted, while on the other hand the character of the ash may be such as to allow a high fuel consumption.

Certain types of fuel, such as the lignites of the United States, permit a high rate of fuel consumption, especially in producers of the down-draft type. Plants are in operation which are consuming more than 40 pounds of lignite per square foot of fuel-bed area per hour, but the majority of producers do not gasify ordinary fuels at any such rate. It is true that suction and pressure producers may be made to gasify comparatively large quantities of fuel per hour for relatively short periods, but in actual operation with ordinary grades of fuel it is doubtful if the consumption will exceed 15 to 16 pounds per square foot of fuel-bed area. The normal figure seems to be much nearer 10 pounds, although, of course, some variation should be allowed for the "workability of the fuel." Even 10 pounds may be a high figure in the case of fuels having a large percentage of ash or a sulphur content that tends to produce serious clinkering.

Of late considerable emphasis has been laid upon the rate of fuel consumption and the tendency to overrate producer plants for power purposes, and manufacturers of producers are giving these matters much consideration.

The depth of the fuel bed carried in the various plants seems to differ considerably. It is essential to have the fuel bed at all times deep enough to properly reduce the carbon dioxide to carbon monoxide. It is also important that the fuel bed be deep enough to prevent excessive heating and burning of the gas and the formation of large channels by the draft. The proper depth of the incandescent zone will of necessity vary materially with the character of the fuel, but in general will be from 2 to 4 feet.

GAS YIELD OF FUELS.

The quantity of producer gas derived from a ton of fuel will vary according to the fuel used, the type of producer plant, and the method of operating. At the St. Louis plant of the Geological Survey the number of cubic feet of gas produced from various fuels in an up-draft pressure producer per pound of fuel was as follows:

Quantity of gas produced per pound of fuel in an up-draft pressure producer.

Character of fuel.	Average.		Maximum.		Minimum.	
	As fired.	Dry.	As fired.	Dry.	As fired.	Dry.
	Cubic feet.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
Bituminous coal	60.5	64.7	100.8	103.5	37.0	40.9
Lignite	35.8	45.7	45.9	52.8	26.1	38.8
Peat	30.3	38.3				

The relation of this gas production to the calorific power of the fuel is shown in figure 8.

Based on the above averages the yield of gas, in cubic feet per pound of dry fuel, which may be expected in this type of producer from various fuels is, roughly, as follows: Coke or charcoal, 90; anthracite, 75; bituminous coal, 65; lignite, 46; and peat, 38.

On the basis of the Survey's tests the gas yield and the heat value of the gas per ton of fuel as fired are approximately as follows:

Yield and heat value of gas per ton of fuel as fired in an up-draft pressure producer.

Character of fuel.	Cubic feet of gas per ton of fuel as fired.	B. t. u. in gas per cubic foot.	B. t. u. in gas per ton of fuel as fired.
Coke or charcoal	170,000	140	23,800,000
Anthracite	140,000	135	19,000,000
Bituminous coal	120,000	152	18,300,000
Lignite	72,000	158	11,400,000
Peat	60,000	175	10,500,000

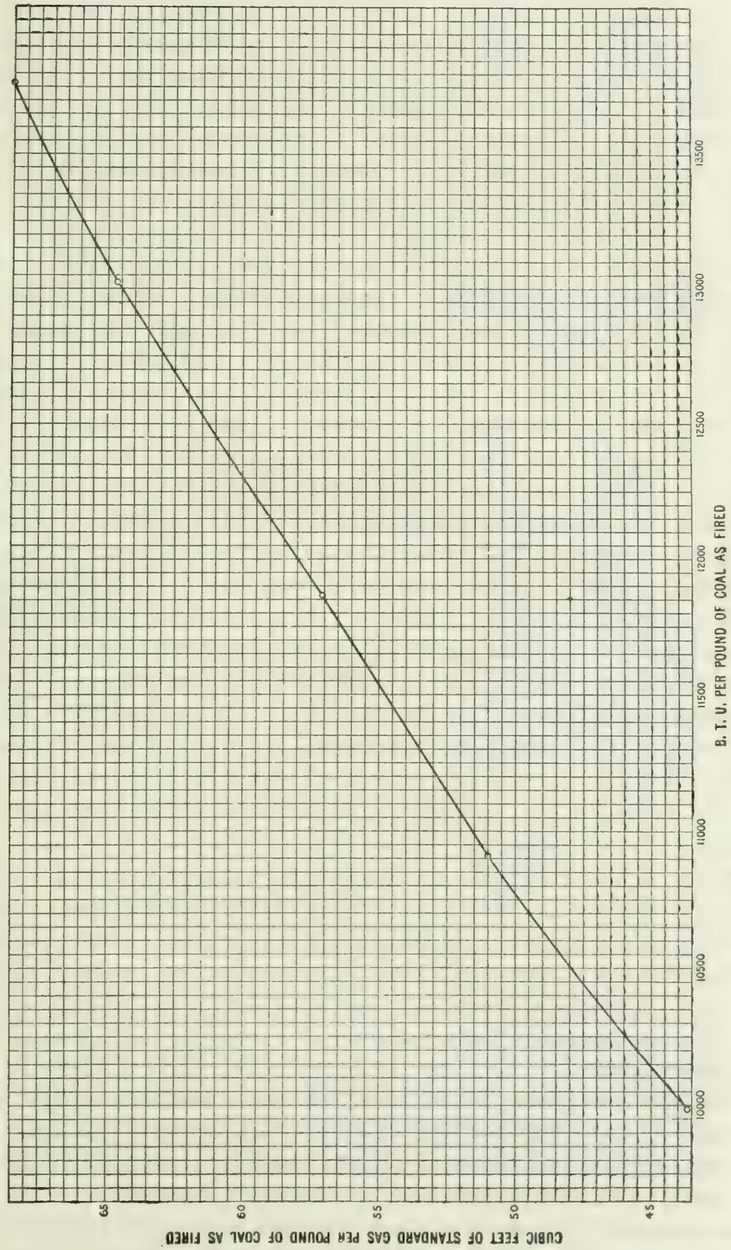

FIGURE 8.—Relation of volume of standard gas generated to calorific power of fuel.

ESSENTIAL FACTORS IN THE PRODUCTION OF GAS OF UNIFORM QUALITY.

RATIO OF AIR AND STEAM IN THE BLAST.

It is essential in gas-producer work that the quantity of gas developed be made to vary with the demands of the plant. In order that the fuel bed may be maintained in good working condition, it is important that the proportions of air and steam supplied be properly adjusted. An excess of air naturally causes an increase in the temperature of the fuel bed and tends to promote complete combustion. This means an excessive quantity of carbon dioxide in the gas produced and a reduction of the quantity of carbon monoxide below the proportion desired. Too much steam lowers the tempertture of the fuel bed to such an extent as to render the making of good gas practically impossible. Of course, the two conditions mentioned are extremes, but it is possible to find, even in plants operating under commercial conditions, great fluctuations in the quality of the gas that are directly due to changes in the proportion of air to steam in the blast. Such irregularities are particularly bad in the case of producers generating gas for power purposes, although they may be equally bad where the gas is used in certain types of metallurgical work. Some method of regulating both the air and the steam supply seems essential. Many of the manufacturers claim to have automatic devices for this purpose, and while it is true that some of these work satisfactorily when the load fluctuations are not extreme, it is questionable whether they meet all the requirements when the demands fluctuate rapidly from no load to full load or from extremely low loads to high ones.

QUANTITY OF STEAM REQUIRED.

Definite figures regarding the quantity of steam required by producers per pound of coal fired are available for European plants operating on certain well-tried fuels. For example, in Belgium with good grades of anthracite small suction-producer plants require from 0.7 to 1 pound of water for the vaporizer for each pound of coal fired, and the scrubber water amounts to from 10 to 15 pounds per pound of coal fired. Although it is true that fairly definite figures may be had for similar types of installations in this country using anthracite, it is equally true that at the present time no data that may be regarded as absolutely reliable and conclusive can be given for plants in the United States operating on bituminous coal. It is to be expected that the quantity of moisture required for successful gas production will vary greatly with the kind of fuel and the percentage of moisture which it contains at the time of firing. At present, however, little or no information relating to this matter is available for any considerable variety of fuels.

One writer on the subject states that for good average working in an ordinary producer 6 per cent of the weight of the blast, or about 10 per cent of its volume, may be steam; that sometimes about 25 per cent more steam than this is used and the weight of the steam may be figured as one-third to two-fifths of that of the coal gasified, or approximately a boiler horsepower per ton of coal burned.

Another writer says that the maximum weight of steam per pound of carbon which can be used if the highest efficiency is to be obtained is 0.64 of a pound.

Another states that for steam-raising purposes there should be available not less than 1¼ pounds per brake horsepower hour.

One engineer of large experience has stated that 7 per cent by weight is the maximum quantity of steam which should be used in an ordinary steam-blown producer.

A large number of fuels have been utilized in the survey's tests, but as only one test usually could be made on each fuel, no definite results regarding the quantity of steam required could be obtained. The records show that for the pressure plant used at St. Louis the water required in the vaporizer per pound of coal fired varied from 0.28 to 1.13 pounds. The average for twenty bituminous coals taken at random is 0.69 pound. With the same installation at Norfolk, possibly excepting some slight changes in the air supply, the water consumption per pound of coal fired on a series of coals of practically the same grade showed a variation from 0.69 to 1.12 pounds. It is interesting to note, however, that for a series of tests in which an attempt was made to vary the air and steam supply and at the same time produce a high-grade gas, the quantity of water per pound of coal was steadily reduced, as shown by the following:

Quantity of water per pound of coal fired.

Test—	Pounds.	Test—	Pounds.
No. 1	1.12	No. 4	0.82
No. 2	1.14	No. 5	.77
No. 3	1.04	No. 6	.69

In one plant in Sweden this problem of air and steam supply has been much simplified by drying the fuel (peat) just enough to do away with the necessity of introducing moisture into the blast. It is found that when the peat is air-dried until it contains 30 per cent of moisture no steam is necessary in the operation of the plant. If the percentage of moisture in the fuel is reduced below this point steam is required, and if the percentage amounts to more than 30 per cent there is an excess of moisture and chilling of the fuel bed results. There is room for much careful study of this question of proper steam supply, as affecting both gas production and clinkering.

Regarding the quantity of water required for cleaning and cooling the gas, different writers state:

"One gallon of water per brake horsepower per hour is required for cooling the gas, or rather a little more than this."

"The amount of water required to thoroughly clean producer gas in fans depends very much upon the arrangements for cooling and scrubbing the gas when it leaves the producer before it enters the fans. A very common allowance is 1 gallon of water for each fan for every 80 cubic feet of gas passing, or 1 gallon of water per 40 cubic feet of gas washed. This water can be used over again after the tar has been skimmed off, so that the actual water consumption is not a serious matter."

"When atmospheric coolers are adopted, the water required is one-fifth of a gallon per brake horsepower hour for cleaning the gas in the washers."

It is obvious that the quantity of water required in the generation of the gas and in the cleaning process varies according to the type of producer plant, the character of the fuel used, the methods of operation, and the efficiency of the scrubbing devices.

DEPTH OF FUEL BED.

Another factor that has considerable effect upon the quality of the gas produced is the depth of the fuel bed. If the bed is too thin, so that it becomes highly incandescent throughout, there is usually an excess of carbon dioxide in the gas owing to a lack of sufficient carbon to reduce the dioxide to monoxide. Furthermore, the temperature of the outgoing gas is high and the heat carried away by the gas is excessive. With a comparatively deep fuel bed these difficulties are overcome and much of the heat otherwise carried away is absorbed by the fuel bed and utilized to advantage in the gas-making processes.

CHANNELING.

The absence of channels or blowholes in the fuel bed is also very important. The operator should prevent the formation of such channels, but if they do form they should be promptly closed. There is, of course, a tendency of the gas and air blast to rush up through these holes, whether they are close to the walls of the producer or in the center of the bed. Channels often result from a thin fuel bed or from forcing the plant. In the case of the pressure producer an effort should be made to keep the fuel bed as close to a uniform level as is consistent with successful operation. To allow the fuel-bed level to rise and then to grind down a large mass of ashes is poor economy of time, and often results in an irregular and poor quality of gas, as well as in the formation of the channels just referred to.

DISTRIBUTION OF BLAST.

Another factor which influences the quality of the gas and the successful and efficient operation of the plant to a marked extent is the distribution of the blast. If the air and steam are not properly distributed over the full area of the fuel bed, the conditions which prevail throughout the producer will vary greatly, the quality of the gas will be seriously affected, and the whole operation of the plant will be made difficult. Some portions of the bed will tend to get too hot, while other portions will be chilled, resulting in the local formation of clinker which may be detrimental to successful manipulation. A special report relating to the wide variation in temperature due to localization of draft is given in Bulletin 393 of the United States Geological Survey.

There are undoubtedly other factors that influence the quality of gas to a certain extent, such as size of fuel, porosity of fuel, etc.

GAS CLEANING AND TAR REMOVAL.

When producer gas is used under boilers, and also in many metallurgical and other heating processes, impurities in the gas, as well as dust and ashes, are in no way detrimental to successful operation. Under such conditions expensive equipment for gas cleaning is unnecessary, and the gas may be taken directly from the generator to the furnace in which it is to be burned. As a result the gas reaches the furnace at a high temperature, which aids in maintaining favorable combustion conditions and is also a factor in the high efficiency obtained. In gas as it comes from the generator there are usually a number of hydrocarbon compounds and tar vapors which condense upon cooling. These appear in the hot gas in such form as to be readily burned, and add materially to the total quantity of heat derived.

NECESSITY OF COOL, CLEAN GAS FOR ENGINE USE.

When, however, the gas is to be used in an engine, it is imperative that no tarry products be allowed to collect in the valves and passageways leading to the engine, and also that all grit and dust be kept from the inside of the engine cylinder in order to prevent damage by scouring. Under these conditions it is exceedingly important that the gas be properly cleaned. In addition, it is desirable to send the gas to the engine at a low temperature, as the cubic content of the engine cylinder is a fixed quantity and a much larger quantity of heat energy can be put into the given space if the gas is cold than if the gas is hot. It is desirable, then, after the gas leaves the generator and before it reaches the engine, to free the gas from all dust, soot, ash, and other similar material, to remove all tar vapors which upon condensation would cause trouble, and also to cool the gas to as low a temperature as is consistent with conditions. This process of removing the impurities is called scrubbing and is described on page 19. During this scrubbing process the gas is usually cooled to or a little below the temperature of the surrounding atmosphere. The cooling process also tends to dry the gas to a certain extent, although dry scrubbers are frequently installed for this purpose.

If charcoal, coke, or anthracite is the fuel used, the percentage of tar in the gas is small, and hence, with a proper scrubbing device, little or no tar is usually carried to the engine. Still, it is not always possible to remove all of the tar, and it then becomes necessary to see that the engine valves and passageways and the engine govornor are properly cleaned at frequent intervals.

In the case of bituminous coal, lignite, peat, and other tarry fuels the scrubbing process alone is not sufficient to remove the tar, and it is essential that more effective means be employed.

MECHANICAL EXTRACTION OF TAR AND ITS OBJECTIONS.

The method of tar removal in vogue is by means of the mechanical tar extractor. A general description of such a device will be found on page 28. The details of the various extractors differ somewhat, but the essential feature is a disk or fan rotating at high velocity, through which the gas with its tarry constituents passes accompanied by a liberal supply of cold water. The water containing the tar and foreign matter is thrown by centrifugal action to the outer rim of the revolving disk or disks and passes to a water seal, from which the tar can be readily removed when desired. The principal objections to this method of procedure are:

(*a*) The removal of the tar involves a serious loss in the heat value of the gas produced per pound of fuel, as the tar represents a large percentage of the total heat value of the fuel.

(*b*) The tar is usually a nuisance about the plant as it is a dirty, disagreeable substance to handle, can not be turned into ordinary sewer systems, and seldom finds a ready market for commercial purposes.

The indications are that a much more general use is made of tar from producer plants in Europe than from those in this country. One method of using this material abroad is to mix it with ashes from the producer and then spread the mixture in the yards for walks, roads, etc., At one installation of 20,000 horsepower the tar, of which there is necessarily a large output, is sold for roofing, paving, and briquetting purposes, and a limited portion is sent to tar distilleries. At another plant visited a special equipment is installed for the proper handling and preparation of this material for commercial use. The tar water runs into a large vat or cistern, and the tar is separated to a reasonable extent as the mixture passes over a series of screens. The tar is then drawn off into a large tank in the bottom of which are exhaust-steam pipes. By means of the hot pipes the tar is kept sufficiently warm to be pumped through a pipe line to tank cars on the nearby railroad. The tar as shipped often contains as high as 20 per cent of water.

The average weight of water-free tar recovered in this installation is 90 pounds per ton of fuel burned. The tar is used as pitch for a binder for fuel briquets and in the manufacture of various medicines. The price received per ton of water-free tar is about $4.25, which amounts to a return of approximately 19 cents per ton of coal fired, not taking into account fixed charges and labor expenses of separating the tar, which, however, amount to little.

CONVERSION OF TAR INTO FIXED GASES.

Owing to the reasons mentioned the mechanical extraction of tar is undesirable, and many attempts have been made to utilize the hydrocarbon compounds and tarry vapors directly in the process of gas making by passing them through an incandescent fuel bed and transforming them thus into permanent gases. This process has been undertaken in many different ways. One method which is in use to some extent abroad is that of distilling the tar vapors from the fresh fuel at the top of the producer and then passing the products of distillation through a passageway outside of the producer shell to the lower portion of the gas generator and there directing these vapors into the incandescent bed. Under these conditions it is probable that little of the tar is transformed into combustible gas, as the larger part is undoubtedly burned. Still, this method of tar disposal is helpful. A larger portion of the carbon in the fuel remains for gas formation, as a part of the combustion is maintained by burning the tar instead of the fuel itself. There are many varieties of this general method of utilizing the tar, but up to the present they have not proved of sufficient commercial importance to attract general attention.

Installations of this character are found occasionally in Europe, but, as is true at practically all plants abroad, the fuels used are limited to those low in ash, low in tar (usually not over 7 per cent), and noncaking.

Another method much used in this country for transforming the tar vapors into permanent gases is by means of the down-draft type of producer described on pages 28–30. As indicated in the description, the vapors and gases distilled from the fresh fuel charged at the top of the producer are drawn down by suction through the incandescent fuel bed in the central and lower portion of the generator. The supposition is that these tarry vapors when subjected to the high temperature of the incandescent fuel bed in conjunction with a restricted air supply are converted into fixed gases, which become part of the gas mixture drawn out by the exhauster and sent to the gas holders. Under excellent operating conditions this change practically takes place, and, although a small portion of the tar vapors may be burned in passing into the incandescent bed, a clean gas free from tar and lampblack is developed. If the conditions are not quite so good and the temperature of the incandescent fuel bed is either too high or too low, difficulty is experienced in generating a clean gas. When the temperature is too low for the complete conversion of the hydrocarbon vapors a certain quantity of tar will pass through the system. This quantity is small and with most fuels is negligible, although experience has shown that it is practically impossible to absolutely eliminate the production of tar from a few varieties of bituminous coal especially high in tar-producing compounds.

Under certain operating conditions some of the carbon, owing to the restricted air supply, will be liberated in the form of fine, oily soot or lampblack. The formation of lampblack in down-draft plants is frequent, and satisfactory removal is somewhat difficult. No great harm results from this material in the majority of plants, although it is nearly as objectionable about a plant as tar. It is, of course, more easily disposed of and the quantity deposited is relatively small. As far as experience at the Survey's plants has shown there seems to be no injurious effect from lampblack in the engine cylinders, but the same may be said of tar. The difficulty with such material is not in the engine cylinders themselves, but in the passages, valve connections, governing attachments, and other mechanisms which may become clogged by these substances. The removal of soot or lampblack from the gas necessitates complete cleaning systems, as illustrated by the wet and dry scrubbers shown in Plate IV (p. 28).

The opinions of those most familiar with the various processes of manufacturing producer gas from bituminous coal and other tarry fuels differ widely regarding the wisdom of attempting to transform the tarry compounds into permanent gases. The down-draft principle does not seem to be so popular in Europe as it is in this country. In spite of the many objections offered to the down-draft system it is interesting to note that over 50 per cent of the total horsepower developed by producer-gas power plants in the United States is derived from down-draft installations, and that plants of this type represent a large percentage of the total number of installations operating upon bituminous coal and lignite. As indicated in the general discussion regarding the labor required in operating down-draft plants, the greatest drawback is not this question of converting the tar into permanent gases, for in this such plants are fairly successful, but the excessive labor involved in ash removal and in general cleaning, which is required under normal conditions about once a week.

LABOR REQUIRED IN OPERATING PRODUCER PLANTS.

GENERAL CONSIDERATIONS AND DATA.

One of the great recommendations for the suction-producer plant, aside from its natural fuel economy, is the small amount of labor and attention required when the fuel used is satisfactory, the producer-load factor is properly adjusted, and the operator understands the theory of the plant. It frequently happens in installations of moderate size, say from 25 to 100 horsepower, that the service required of the operator amounts to only 2 or 3 hours per working day, and the remainder of his time can be utilized in any way desired. If the fuel magazine is large, if the air and steam supply is automatically regulated with some degree of precision, and if the load upon the producer is not excessive, it is not difficult to meet the conditions mentioned above, but in installations in which these points are not taken into consideration, or in which incompetent operators are employed, the results are often exceedingly disappointing.

In general, pressure and down-draft plants are installed where relatively large units are desired. These units ordinarily run from 250 to several thousand horsepower, and hence it is practically imperative that one or more operators give their entire time to the producer-gas plant. The character of the employees required, the pay for their services, and the number of men necessary in a producer room will depend largely upon the general nature of the manufacturing plant. In installations in which a chief operating engineer of experience is required in the engine and generator room the labor for the producers may be reduced to a minimum. In one installation of 1,500 or more horsepower the producer labor amounts to one man per shift at $16 per week, with additional labor on Sundays to assist in cleaning the plant.

Considerable information relating to the details of such plants and the labor required in their operation is contained in the data following obtained by a personal inspection of sixty-nine producer-gas power installations in the United States.

Summarized particulars of producer-gas power installations visited.

Plant No.	Producers.				Fuel.			Water supply.	Number of men required each shift.
	Type.	Number installed.	Total rated capacity, horsepower.	Internal diameter.	Kind and size.	Amount used (approximate).	Method of charging.		
				In.		*Pounds.*			
1	Suction	1	25		Anth. pea	1.25 per b. h. p. hr.			
2	...do	1	25		...do		3 times a day	City mains	One.
3	...do	1	30		Anth. buck.	300 per day	Once an hour.		5 hrs. time of one.
4	...do	1	30		Anth. pea				Part time of one.
5	...do	1	35		Anth. and semi-anth., mixed.	1.6 per b. h. p. hr.		City mains	One (12 hr. shifts).
6	...do	1	50		Anth. pea	400 per day	Varies with load.	Well	One 2 hrs. per day.
7	...do	1	50	28	...do	450–500 p. d.	Twice a day	...do	Do.
8	...do	1	50		...do			Pressure main.	
9	...do	1	50		...do	240 per day	3 times a day	City mains	Do.
10	...do	1	50					...do	
11	...do	1	50		Anth. pea	300–400 p. d.	3 times a day	...do	Do.
12	...do	1	50	36	...do	700 per day	...do	Well	One.
13	...do	1	50	28	...do	1,340 per day	Every 30 mins.	Pressure main.	Part time of two.
14	...do	1	50	36	...do	450–500 per day.	Fill every morning, charge as needed.	City mains	One 2 hrs. per day.
15	...do	1	50		...do	300 per day	Twice a day	Well	Do.
16	...do	1	50	30	...do	550 per day	Every 25 to 30 mins.	City water	Do.
17	...do	1	50	28	...do	650 per day	4 times a day	Well	Half time of one.
18	...do	1	60		Charcoal	1 per b. h. p. hr.		City mains	One.
19	...do	1	60		Anth. pea	335 per day	Twice a day		2 hrs. time of one.
20	...do	1	60		Anth. buck.	1-1.5 per b. h. p. hr.	3 times a day		Part time of two.
21	...do	1	60		Anth. pea			Pressure main.	
22	...do	1	70		...do	300 in 7 hrs		...do	One.
23	...do	1	75						
24	...do	1	75		Anth. pea				Part time of one.
25	...do	1	80		...do				Two.
26	...do	1	95		...do	1,000	6 times a day	Well	Do.
27	...do	1	100		...do			City mains	One.
28	...do	1	100		...do			...do	
29	...do	1	100		...do				
30	...do	1	100	36	...do	700 per day	About once an hour.	Well	Do.
31	...do	1	100		...do	1,000 – 1,200 per day.	3 or 4 times a day.	City water with cooling tower.	Do.
32	...do	1	120		...do	1,000 – 1,200 per day.	...do	City mains	Do.
33	...do	1	120		...do	800–900 per day.	Twice a day.	Wells	One 4 hrs. per day.
34	...do	1	125		...do	Less than 1 per b. h. p. hr.	5 times in 24 hrs.		One.
35	...do	1	125		...do				
36	...do	1	125		...do	850 per day	3 or 4 times a day.	City mains	Do.
37	...do	1	130		...do	875 per day	4 times a day	River	Do.
38	...do	2	(a)		...do				
39	...do	1	150		...do	1.8 per b. h. p. hr. inc. stand-by.	70 lbs. each hour.		Do.
40	...do	1	150	54	...do	500–600 per day.	Every 2 to 2½ hours.	Well	Do.
41	...do	1	200		Anth. buck.	136 per hr			

[a] One 125 horsepower; one not stated.

Summarized particulars of producer-gas power installations visited—Continued.

Plant No.	Producers.				Fuel.			Water supply.	Number of men required each shift.
	Type.	Number installed.	Total rated capacity, horsepower.	Internal diameter.	Kind and size.	Amount used (approximate).	Method of charging.		
				In.		*Pounds.*			
4	Suction	1	200	84	Anth. pea.	1,000 per day	125 lbs. at a charge when needed.	City mains	One.
43	...do	2	200		...do	650 per day	Every hour and a half.	Pressure main.	Two.
44	...do	1	200	60	...do	900 per day	3 times a day	City mains	One.
45	...do	1	200		...do	2 per b. h. p. hr.	1,000 lbs. charged each morning.		Part time of one.[a]
46	...do	1	300		...do	2,200 per day	According to need.	River	Part time three.
47	...do	2	300	42	...do	1,800 per day	Every 40 mins.	City water	Two.
48	...do	2	350	54 66	Anth. buck., No. 1.	3,800 per day	Every 6 hrs.	Well	Do.
49	Pressure.	1	85		Anth. pea.	800-1,000 per day.	175 lbs. at a charge when needed.	City mains	Do.
50	...do	1	200		Anth. egg.	1,600 per day	4 times a day	Well	Do.
51	...do	1	200		Anth. pea.	2,700-3,200 per day.	Every hour.	City mains	Do.
52	...do	1	250	84	...do	1,700-1,800 per day.	150 lbs. about once an hour.	...do	Part time of two.
53	...do	1	250		Bit				Full time of one and part time of one.
54	...do	1	250	84	Anth. pea.	3,000 per day	3 or 4 times a day.	Saltwater from sea.	Part time of one.
55	...do	1	300		...do	1,000 per 540 kw. hrs.			Two.
56	...do	1	300		...do	1,800 per day	Varies	River	Do.
57	...do	2	400	84	...do	1.33 per b. h. p. hr. or 7,000 per day.	Every 2 hrs.		Full time of two and part time of one.
58	...do	2	500	84	Bit. (New River).	5,300 per day (light load).	Every 20 to 30 mins.	Well; also city main.	Two.
59	...do	2	600	96	Anth. pea.		Varies; about once an hour.	River	Three.
60	...do	2	600	108	Anth. buck., No. 2.	10,000-11,000 per day.	About every hour.	...do	Do.
1	...do	3	600		Anth. buck., No. 1.	5,000 per day	Every 2 hrs.	...do	Two.
62	...do	3	750	96	Anth. pea.		According to need.		Three.
63	...do	3	750	96	Anth. buck., No. 1.	12,000 per day.	Continuous feed.		Do.
64	...do	1	1,750		Anth. pea.				
65	Down draft.	1	1,000		Bit				
66	...do	2	1,000		...do	15,000 per day.	Shovelful at a time.	Well	Five.
67	...do	1	1,500		...do	1.4 per kw. hr.		Brook	Three.
68	...do	6	3,000	108	...do	Varies much	Shovelful at a time.	Wells	Do.
69	...do	1	4,000		...do				

[a] Plus general supervision.

Summarized particulars of producer-gas power installations visited—Continued.

Plant No.	Engines.					Hours operated daily.	Use of power.
	Type	Number installed.	Rated capacity, horsepower.	Average load, horsepower.	Power transmission.		
1	1-cylinder, horizontal, 4-cycle, single-acting.	1	25	......	Belt drive to shaft.	(*a*)	Gristmill machinery.
2	.....do.....	1	27	(*b*)	.....do.....	(*c*)	Operating air compressors, stone surfacers, roughers, etc.
3	.....do.....	1	30	28	.....do.....	10	Machine shops.
4	.....do.....	1	27	20	.....do.....	10	Brick machinery.
5	.....do.....	1	35	(*d*)	Belt drive to generator.	24	Lighting restaurants, cafés, etc., running fans and ice-making machine. (Larger engine being installed.)
6	.....do.....	1	38	30	Belt drive to shaft.	10	Carriage shop.
7	.....do.....	1	50	40	.....do.....	10	Woodworking shop.
8	.....do.....	2	50	(*e*)	Gear drive to pumps.	8–12	Pumping station.
9	.....do.....	1	25	18	Belt drive to shaft.	10	Grinding and polishing.
10	.....do.....	1	38	......	.....do.....	......	Plant not running.
11	.....do.....	1	35	26	.....do.....	11–18	Coffee-roasting mill.
12	2-cylinder, tandem, single-acting, 4-cycle.	1	60	35	Belt drive to a. c. generator.	11	Machineshop and lights.
13	2-cylinder, vertical, single-acting, 4-cycle.	1	35	35	Belt drive to centrifugal pump.	24	Pumping station.
14	3-cylinder, vertical, single-acting, 4-cycle.	1	60	35	Belt drive to shaft.	12	Chocolate grinding and ice machine.
15	1-cylinder, horizontal, single-acting, 4-cycle.	1	20	10	.....do.....	10	Concrete mixer.
16	3-cylinder, vertical, single-acting, 4-cycle.	1	45	......	.....do.....	10	Wire-drawing machines.
17	1-cylinder, horizontal, single-acting, 4-cycle.	1	38	......	.....do.....	10	Factory.
18	2-cylinder, vertical, single-acting, 4-cycle.	1	*f* 68	......	.....do.....	10	Shoe machinery and a 100-light dynamo.
19	1-cylinder, horizontal, single-acting, 4-cycle.	1	25	20	.....do.....	10	Shop machinery.
20	2-cylinder, vertical, single-acting, 4-cycle.	1	50	30	.....do.....	10	225 sewing machines and a 12½-kw. dynamo for lights.
21	1-cylinder, horizontal, 4-cycle.	1	80	(*g*)	Belt drive.....	......	Town pumping and lighting station.
22	1-cylinder, horizontal, single-acting, 4-cycle.	1	65	20	Gear drive to pumps.	(*h*)	Pumping station.
23	3-cylinder, vertical, single-acting, 4-cycle.	1	75	......	Belt drive to shaft.	......	Machinery for grinding, polishing, etc.
24	1-cylinder, horizontal, single-acting, 4-cycle.	1	60	......	......	20	Shops.
25	3-cylinder, vertical, single-acting, 4-cycle.	1	70	(*i*)	......	......	Street and house lighting.
26	1-cylinder, horizontal, single-acting, 4-cycle.	2	80	......	Belt drive to shaft.	9	Foundry and shops.
27	3-cylinder, vertical, single-acting, 4-cycle.	1	55	......	Belt drive to 37.5-kw. generator.	24	Operating printing presses and lighting the block.
28	One 3-cylinder, vertical, single-acting, 4-cycle, and one 1-cylinder, horizontal, single-acting, 4-cycle.	2	100	......	Belt drive to shaft.	......	Machine shop.
29	......	......	......	......	......	......	Used only for testing gas engines.
30	2-cylinder, vertical, single-acting, 4-cycle.	1	100	......	Belt drive to shaft.	9½	Grinding and polishing.
31	3-cylinder, vertical, single-acting, 4-cycle.	1	100	60	Belt drive to generator.	10½	Machine shop and light.
32	1-cylinder, horizontal, single-acting, 4-cycle.	2	110	......	Belt drive to shaft.	9	Light and power for factory.
33	.....do.....	2	88	60	.....do.....	11	Gristmill and elevators.
34	3-cylinder, vertical, single-acting, 4-cycle.	1	75	90	Belt drive to shaft.	22½	Shops.

[a] Varying.

[b] Variable; over 30 horsepower at times.

[c] Usually 9; 12 at present.

[d] Variable; 1 to 24 kilowatts.

[e] 50 horsepower at times.

[f] By test.

[g] 15 horsepower for pumping; amount for lighting unknown.

[h] Varying; often 22.

[i] 60 horsepower at times.

Summarized particulars of producer-gas power installations visited—Continued.

Plant No.	Engines.					Hours operated daily.	Use of power.
	Type.	Number installed.	Rated capacity, horsepower.	Average load, horsepower.	Power transmission.		
35	2-cylinder, vertical, single-acting, 4-cycle.	1	125	......	....	11	Grain-elevator machinery.
36	1-cylinder, horizontal, single-acting, 4-cycle.	1	60	40	Belt drive to generator.	10	Light and power for shops; gas used for heating also.
37	.....do.....................	2	120	60	.....do............	11	Shops and factory.
38	2-cylinder, vertical, single-acting, 4-cycle.	1	150	......	....	....	Factory purposes.
39	3-cylinder, vertical, 4-cycle..	2	125	65	Direct connected to generators.	11	Electric power for factory and lighting.
40	3-cylinder, vertical, single-acting, 4-cycle.	1	89	45	.....do............	10	Light and small machines.
41	1-cylinder, horizontal, single-acting, 4-cycle.	2	200	......	Belt drive to generator.	11	Factory purposes.
42	One 3-cylinder and one 2-cylinder, vertical, single-acting, 4-cycle.	2	210	70	One belt drive; the other direct connected to generator.	10	Shops.
43	3-cylinder, vertical, single-acting, 4-cycle.	2	152	50	Gear drive to pumps.	9–10	Pumping station. (Duplicate plant.)
44	.....do.....................	2	200	90	Direct connected to generator.	11	Machine shop.
45	.....do.....................	1	100	......	Belt drive to generator.	....	Factory purposes.
46	2-cylinder, tandem, single-acting, 4-cycle.	1	200	160	Belt drive to generator.	11	Grinding and general purposes.
47	3-cylinder, vertical, single-acting, 4-cycle.	3	300	100	Direct connected to generator.	14	Charging station garage.
48	.....do.....................	4	400	160	Two direct connected to generators; two metal-link belt drive to compressors.	24	Refrigeration, light, and power. (Duplicate plant.)
49	.....do.....................	1	85	......	Belt drive to shaft.	11	Light and power for factory.
50	1-cylinder, horizontal, single-acting, 4-cycle.	2	175	130	One, direct connected to generator; other, belt drive to generator.	10	Shops.
51	3-cylinder, vertical, single-acting, 4-cycle.	2	180	160	Direct connected to generator.	24	Generating current for electrolysis.
52	.....do.....................	(a)	(b)	60	.....do............	11	Light and power in cleaning and dyeing plant. Gas also used for heating flatirons.
53	Horizontal, tandem, double-acting, 4 cycle.	1	250	250	.....do............	11	
54	1-cylinder, horizontal, single-acting, 4-cycle.	2	250	......	One, direct connected to generator; other, belt drive to shaft.	10	Machine shop, cranes, and light.
55	3-cylinder, vertical, single-acting, 4-cycle.	3	415	(c)	Direct connected to a. c. generators.	[d] 24	Town lighting, both for streets and dwellings.
56	.....do.....................	1	270	150	Direct connected to generator.	11	Machine shop and foundry.
57	One 2-cylinder, vertical, single-acting; two horizontal, 2-cylinder, single-acting; five (in 1906—three in 1908) horizontal, 1-cylinder, single-acting, 4-cycle.	(e)	(f)	(g)	3 belted to generators; 3 belted to compressors; 2 belted to conveyor shafting.	(h)	Air and gas compressing, ash and coal conveyors, electric lighting.
58	2-cylinder, tandem, double-acting, 4-cycle.	1	500	475	Direct connected to generator.	12	Machine shop and lights.
59	3-cylinder, vertical, single-acting, 4-cycle.	3	900	450	.....do............	24	Shops and electric cranes.
60	2-cylinder, tandem, double-acting, 4-cycle.	1	470	390	.....do............	10¼	Wire-mill machinery.

[a] 1 in 1906; 2 in 1908.

[b] 90 in 1906; 210 in 1908.

[c] 20 to 90 kilowatts.

[d] 7 days per week.

[e] 8 in 1906; 6 in 1908.

[f] 460 in 1906; 400 in 1908.

[g] Night, 100 horsepower; day, 160 horsepower.

[h] One 21 hours, two 13 hours, three 18 hours, one 6 hours, one 14 to 20 hours.

Summarized particulars of producer-gas power installations visited—Continued.

Plant No.	Engines.					Hours operated daily.	Use of power.
	Type.	Number installed.	Rated capacity, horsepower.	Average load, horsepower.	Power transmission.		
61	3-cylinder, vertical, single-acting, 4-cycle.	2	350	275	Direct connected to generator.	24	Machine shop and lights.
62	Two 3-cylinder, vertical, and one 2-cylinder, horizontal, single-acting, 4-cycle.	3	710	......	One, belt drive; two, direct connected to generator.	10	Shops.
63	1-cylinder, horizontal, double-acting, 2-cycle.	1	500	500	Direct connected to line shaft.	24	Paper-mill machinery.
64	.....do.....................	3	1,500	......	Direct connected to generators.	......	Street-railway service.
65	3-cylinder, vertical, single-acting, 4-cycle.	3	700	......	.....do...........	[a] 24	General manufacturing purposes.
66	.....do.....................	4	540	400	.....do...........	10	Machine shop and light.
67	Horizontal, single-acting, twin engines.	2	1,220	......	.....do...........	16	Street-railway service.
68	2-cylinder, tandem, double-acting, 4-cycle.	5	1,750	300	.....do...........	24	Central power station.
69	Vertical, single-acting.......	5	800	800+	.....do...........	14	Shops.

[a] 6½ days per week.

METHODS AND LABOR NECESSARY IN DIFFERENT TYPES OF PLANTS.

SUCTION PLANTS.

In operating a suction plant care is taken to remove the ash and clinker at frequent intervals, which can usually be done without seriously interfering with the operation of the plant. As far as possible the clinker is kept near the grate and the ash is so removed as to keep the incandescent bed just above the grate from becoming clogged. This is essential in order to utilize as little of the power of the engine as possible in the production of the draft.

PRESSURE PLANTS.

In the pressure system, unless grinding down of the ash is carefully looked after, there is a constant accumulation which may prove objectionable. Serious clinkering may take place in the fuel bed but by proper manipulation the clinker may be so broken up that it will descend with the ash and be ground down into the ash pit. With these plants, often set up without a water seal, it is imperative that the regular operation be discontinued occasionally in order that the ash and clinker may be removed from the ash pit. It is possible to run these plants for two or three weeks without serious inconvenience with some types of coal low in ash, provided there is no overload demand on the producer. Generally, however, it is necessary to shut down about once a week for the purpose of removing the ash and clinker. To overcome this objection in installations which do not shut down on Sunday the producer can readily be placed in a water seal, as shown in figure 20 (p. 88), thus allowing the removal of ash and clinker at will without interrupting the operation of the plant.

DOWN-DRAFT PLANTS.

In the down-draft producer the ash and clinker accumulation takes place in the upper part of the coke bed and the lower part of the true fuel bed. The result is that there is no method of grinding down the ash or removing it during the process of operation. Hence the ash bed, and with it the fuel bed, rises higher and higher in the producer until the accumulation makes a shutdown imperative. Whenever possible, advantage is taken of the regular Sunday shutdown for cleaning such plants, but in certain types of installations such shutdowns are not convenient, and it becomes necessary to carry a reserve unit which can be cut in when the unit in operation is cut out. Although this plan is severely criticized by those opposed to the down-draft system, in fairness it should be said that the plan is not essentially different from that regularly employed in the operation of boilers in steam-power plants.

When the ash content of the fuel is high, it frequently becomes necessary to cut out and clean a producer at shorter intervals than every seventh day. An extreme instance of this sort is a plant consisting of three units all under full operation. The fuel used is high in ash, and one unit has to be cleaned every third day, the plant running continuously 24 hours a day 7 days a week. In this way one unit is out of service for cleaning each day. It requires 6 men 8 hours to accomplish the thorough cleaning of the plant and the rebuilding of the fire; or, in other words, it is 8 hours from the time a unit is cut out from this system until it is again contributing gas of good quality. Although, at first glance, the labor involved seems excessive, the case is not extreme when one realizes that each unit is of 1,100 horsepower (3,300 horsepower for the total plant); that the plant is being operated to its full capacity all the time and beyond its rating a good part of the time; and that the total quantity of fuel used in the installation per 24-hour day is 80 or more tons. Computed on this basis, the labor required is practically the same as that for a corresponding steam plant, as far as the matter of cleaning and of handling the ashes is concerned.

IMPORTANCE OF SIMPLIFIED METHODS OF CLEANING.

It will be readily understood that the work of removing ash and clinker from gas producers is more or less expensive, dirty, and exacting. Although charging the fuel is a simple process and generally by no means laborious, yet considerable difficulty may be experienced in holding for long periods men that find any satisfaction in handling the cleaning processes now in vogue in the larger installations.

It seems important that simple and effective methods of cleaning be devised for such installations and that cleaning shall not interrupt the continuous and smooth operation of a plant. Although such methods may not be essential (and are not in use to-day) in the well-tried steam-power plants using coal as fuel and without reserve units, and although the matter of ease of cleaning may be carried too far for commercial success in the manufacture of producers, yet it does seem desirable that the present methods be materially changed and that the labor involved in removing clinker from the interior of producer shells be greatly reduced and simplified. The removal of ash can be made comparatively easy provided clinker production be reduced, but with a large proportion of the fuels available for use in the plants on the market to-day clinkering seems to be a serious matter, and interferes more than anything else except the ignorance and stupidity of the operator with the successful operation of the average plant.

MECHANICALLY STIRRED PRODUCERS.

So much difficulty has been experienced from channeling and clinkering in various producer plants that many attempts have been made to replace hand stoking by mechanical stoking. Various devices have been employed, one of which consists of a stirrer that projects into the fuel bed and is operated from the outside by shafting and gears. In another example the producer itself is divided into two or more transverse sections which are caused to rotate relatively to each other at a moderately slow speed. Other devices have also been tried with more or less success. It is claimed by the advocates of these devices that of necessity they produce more uniform conditions in the fuel bed than can be procured by hand stoking, because, being mechanical, they must operate at regular intervals, are not subject to the whim or indifference of the operator, and because the ash is continually moved and ground down. This uniformity of conditions in the fuel bed naturally tends to produce a more uniform gas, and should result in a relatively large production of gas per square foot of fuel-bed area. Plate III *B* (p. 24) illustrates the mechanism employed in one type of mechanically stirred producer.

The opponents of mechanical stoking claim that since mechanical devices lack judgment the stoking is not done in a manner assuring the highest efficiency and most economical conditions in plants subjected to varying demands. It is also claimed that all such equipment adds materially to the care of a plant, that the apparatus is constantly undergoing repair and failing to respond to the requirements demanded, and that with some types of mechanical stokers the waste of fuel in the ashes is excessive.

It is true that to a certain extent both arguments are valid when different types of installations are taken into account and the various requirements imposed on plants are considered; it is also true that the character of the fuel has much to do with the success or failure of such devices.

EFFICIENCY OF GAS PRODUCERS.

DEFINITION.

As in the case of many engineering appliances considerable confusion exists regarding the term "efficiency" as applied to the gas producer. It is necessary to make the definition so clear that no misunderstanding can arise regarding the intended meaning. In producer practice two commercial efficiencies are usually recognized. It has been the custom in the Survey's tests to define these as "efficiency of conversion and cleaning" and "gas-producer plant efficiency." By the first of these is meant the ratio of the actual number of heat units in the clean, cold gas delivered to the gas holder or engine to the number of heat units in the dry coal actually charged into the producer during a given interval. In determining this efficiency no account is taken of the power required to drive any auxiliaries necessary for the manufacture of the gas and no allowance is made for any fuel used in generating blast steam in plants where this steam is made in an auxiliary boiler. Under ordinary conditions this is the efficiency upon which the manufacturer bases his guarantee, usually expressing it in some such terms as: "We guarantee the gas-generating system to operate commercially when supplied with fuel approved by us and having a heat value of not less than —— B. t. u. per pound of dry fuel, and when handled according to our instructions to deliver in the form of gas —— per cent of the energy contained in the fuel used in the gas generator." As many disputes have already arisen regarding the exact meaning of this guarantee, it is well to have this phraseology made more explicit before the contract for the plant is made in so far as it affects an acceptance test. It is very difficult to secure a satisfactory adjustment of any misunderstanding after the letting of the contract.

This efficiency, as defined above, relates primarily to power installations in which the gas is used in engines, or to other types of plants in which the gas is cooled before being utilized. When used for heating purposes or other applications in which the gas passes directly from the producer to the point of utilization without cleaning or cooling beyond radiation losses, the efficiency of conversion is understood to mean the ratio of the total heat value of the hot gas direct from the producer to the total heat value of the dry coal consumed in the producer during a given interval. This efficiency will usually be considerably higher than the corresponding efficiency for the cool, clean gas, as the hot gas usually carries considerable quantities of tar vapors which add to its heat value but which in cooling are condensed and carried away in the scrubbing process.

The second efficiency, or that of the gas-producer plant, is the ratio of the total heat value of the cold gas delivered to the gas holder or engine during any given interval to the total heat value of the dry coal consumed in the producer and the dry coal required by auxiliary boilers for generating steam, plus the heat value equivalent of any power required for driving auxiliary equipment used in the manufacture of the gas, such as centrifugal tar extractors, cleaners, etc., during the same interval.

HEAT LOSSES.

The principal heat losses in gas-producer operation which seriously affect efficiency are:

(*a*) *Heat lost in the gases.*—The temperature of the gases leaving the generator varies considerably, and usually ranges between 500 and 1,000° F. in producers which are operated properly. In many types of producers advantage is taken of the heat in the gas to generate the steam required by the plant. It is, of course, impossible to utilize all of the heat, and in general producer plants should be so operated that the temperature of the gas entering the scrubbing system shall be as low as is consistent with satisfactory results. The total quantity of heat carried away in the gas is variously estimated by different investigators, but the average loss from this source seems to be about 10 per cent of the total heat value of the gas. The above statement regarding the necessity of keeping the temperature of the gas as low as possible does not, of course, apply to cases where the gas is used directly for heating purposes. Under these conditions the temperature of the gas should be relatively high in order to obtain the maximum efficiency.

(*b*) *Radiation losses.*—The amount of heat lost by radiation varies considerably with the construction of the producer plant. When the producer is small, the lining thin, and no special precautions are taken, the radiation loss may be heavy, and may prove a disagreeable factor if the producer is installed in a small room. Serious difficulty of this character has been experienced with one or two marine installations in necessarily crowded quarters. If the producer walls are thick, and if spaces, filled with a porous, nonconducting material, are left between the brick lining and the outer shell, much of the radiation loss can be prevented. For better protection against radiation losses it is often more desirable to build a number of producers of comparatively small size than to erect an extremely large one. This, however, need not be the case if proper conditions are imposed. In an installation visited in Wales, containing pressure producers of 1,250 horsepower each, the producer shells were jacketed with asbestos. The operating engineer claimed that this jacketing increased the efficiency of the plant 5 per cent.

(*c*) *Heat lost in the ashes.*—In producers which are properly handled and which burn the coal completely the heat loss through ash removal should be exceedingly small. In many plants, however, the fuel is not completely burned, and a large amount of coke is removed with the ashes, thus causing considerable loss. Theoretically it is possible to utilize this coke by putting it back into the producer, but in actual operation serious difficulty has resulted from this practice and in many cases the operators have been forced to abandon it. The loss by way of the ash pile may, therefore, be considerable. Plants have been inspected in which the coke thrown out with the ashes amounted to 25 per cent or more of the total fuel fired. This condition of affairs of course represents unusually careless operation or a misunderstanding of the proper manipulation of such plants. In some cases an independent use has been found for the coke so removed, thus preventing an entire loss in this direction. Although, as stated above, 25 per cent or more of the total fuel fired is sometimes taken out in the form of unburned coke, the average figure is probably not much over 5 to 10 per cent. This loss is entirely distinct from the true heat loss by way of the ashes, which is practically negligible in the best types of producers.

Figure 9 shows the variation of efficiency of conversion and cleaning with the calorific power of the fuels used at the St. Louis station.

Figure 10 in a similar manner shows the relation between efficiency and the rate of firing.

BY-PRODUCT PRODUCER-GAS PLANTS.

THE FIELD OF THE BY-PRODUCT PLANT.

When producer-gas installations are small, not exceeding 3,000 or 4,000 horsepower, the returns do not warrant an attempt to utilize any of the constituents contained in the fuel other than the gas itself. In case, however, the plant is to be of considerable size, say of 5,000 horsepower or more, it is possible not only to secure a large supply of producer gas, but to separate from the fuel certain by-products which are of considerable value. Plants operating on bituminous coal and equipped for by-product recovery not only produce large quantities of gas, but at the same time yield a liberal quantity of sulphate of ammonia. In these installations 80 to 90 pounds of sulphate of ammonia and 140,000 to 160,000 cubic feet of gas are produced from each ton of coal fired.

These plants are of necessity somewhat complicated in their operation and are correspondingly expensive, so that it is seldom deemed a wise commercial venture to install by-product recovery systems in small plants.

Doctors Frank and Caro, of Charlottenberg, Germany, have recently interested themselves in the utilization of peat in by-product plants, and have successfully gasified peat containing 40 per cent of moisture and at the same time recovered a liberal quantity of ammonium sulphate.

The field for these by-product plants in the United States has not as yet been developed, but experience in Europe shows the wisdom of utilizing this process in large central installations using bituminous coal containing a fair percentage of nitrogen. In Doctor Frank's opinion the peat bogs of this country offer unusual opportunities for the successful commercial application of this process. It is reported

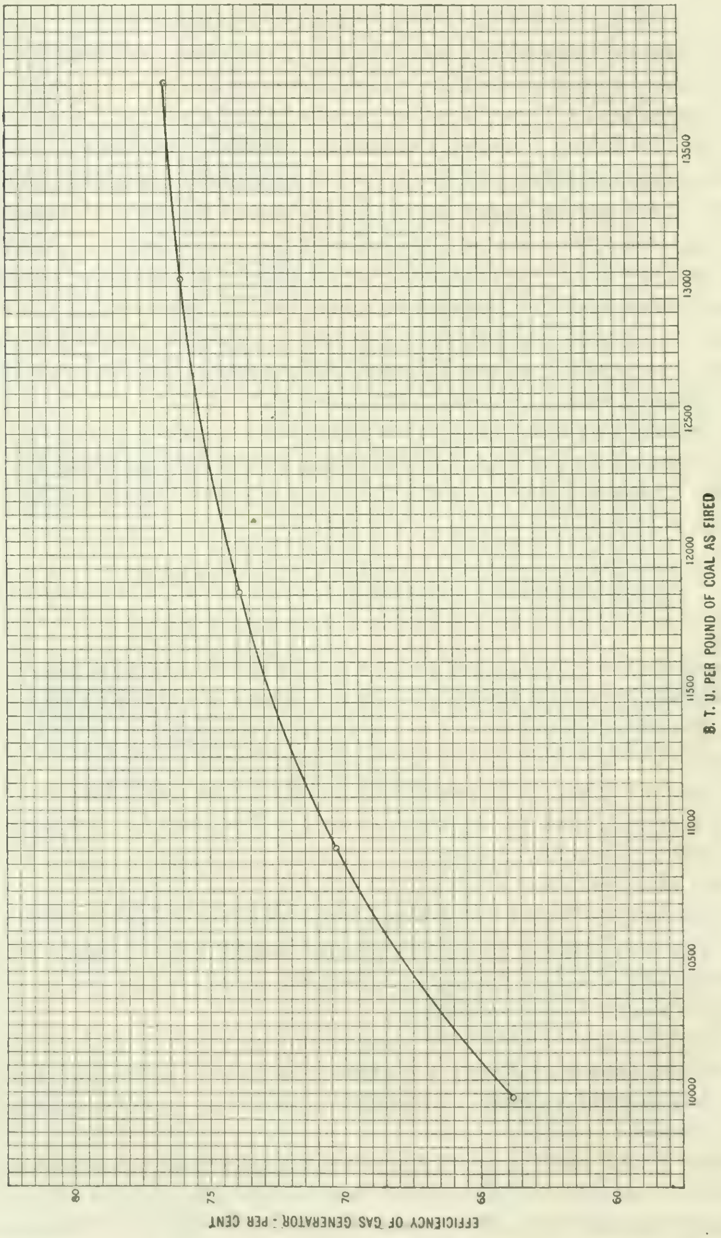

FIGURE 9.—Relation of generator efficiency to calorific power of fuel.

that many of the peats of this country contain more than 2 per cent of nitrogen and in some cases as high as 3 per cent. As calculated by C. A. Davis in his report entitled, "Some Commercial Aspects of Peat as a Source of Chemical Products,"[a] the yield of sulphate of ammonia from a short ton of peat containing 2 per cent of nitrogen amounts to 188 pounds, and from a peat containing 3 per cent, 282 pounds. The market price of sulphate of ammonia is approximately $60 per ton, which makes the above-mentioned yields worth $5.65 and $8.45, respectively, per ton of theoretically dry peat gasified. The financial return from the recovery of this important by-product seems especially inviting when it is realized that, as already stated, the ordinary grades of bituminous coal yield about 90 pounds of sulphate of ammonia per ton. It is sometimes possible to secure a market for the pitch and tar produced as well.

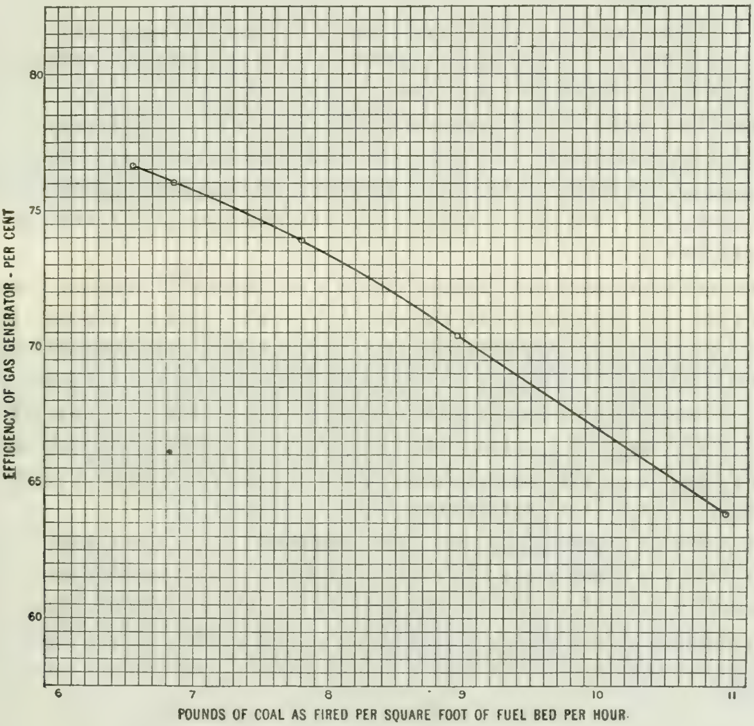

FIGURE 10.—Relation of generator efficiency to rate of firing.

The only by-product plant of this type in the United States at the present time, so far as is known, is at the works of the Solvay Process Co., in Detroit, Mich.

Anthracite coal does not lend itself profitably to this process owing to the small percentage of nitrogen contained and to the high initial price of the fuel, but the cheaper bituminous coals, averaging about

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[a] Economic Geology, vol. 5, January 1910, p. 49.

1.3 per cent of nitrogen, are especially adapted to the successful operation of such plants, provided they are of sufficient capacity to reduce the operating expenses and fixed charges to a reasonable figure per unit of output. Attempts to operate small by-product plants have not proved financially successful. The impression abroad is that no attempt should be made to recover the by-products in plants of less than 4,000-horsepower capacity, although some of much smaller size are in operation.

AN ENGLISH PLANT.

One of the most interesting installations of this type in Europe is the 16,000-horsepower Mond gas plant at Dudley Port, South Staffordshire, England. This plant presents so many interesting features that the following details are given:

There are eight Mond pressure producers with a rated capacity of 2,500 horsepower each. Of these, two are held in reserve, as the plant is operated 24 hours per day. The installation also includes two 250-horsepower vertical single-acting three-cylinder Westinghouse gas engines.

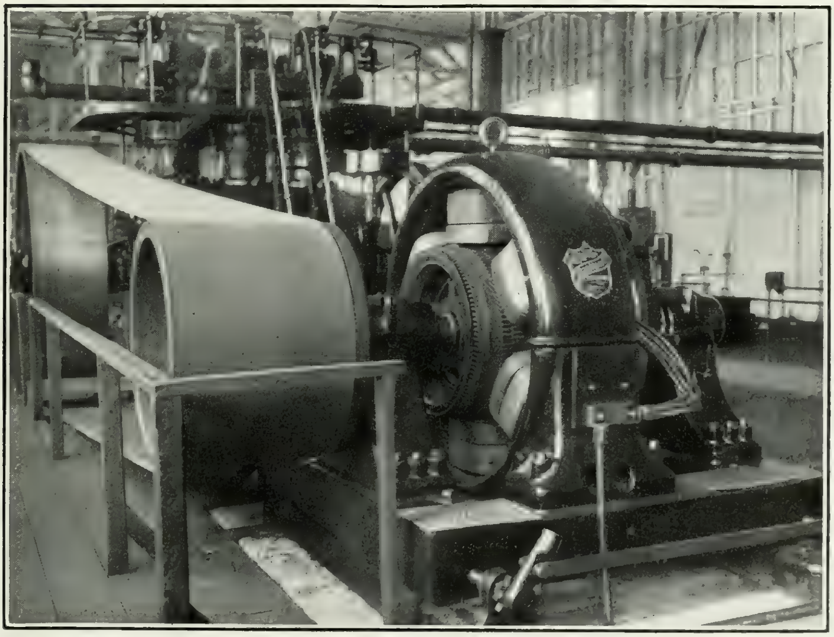
The fuel used may be designated as a considerably broken run-of-mine coal and is reported to contain 8 to 9 per cent of ash and only 1 to 2 per cent of sulphur. It is said that the coal formerly purchased contained from 13 to 23 per cent of ash, and as the price was high the company operating the plant finally obtained its own mines, which yield the better grade of coal indicated. The coal is brought to the plant by canal boats, as shown in Plate VII*A*, which presents a general view of the installation.

The necessary machinery for circulating the acid liquor and water, the boilers for generating the steam, and the other auxiliaries of the plant are installed in the buildings shown. Only a small portion of the gas generated is used in the plant itself, as the main purpose of the project, aside from the recovery of the sulphate of ammonia, is the distribution of producer gas to the manufacturing plants in the neighboring towns.

The outgoing gas lines are shown at the extreme right. The main distributing line is 3 feet in diameter. At the time of my visit (August, 1908) there were 37 miles of gas mains in use, the longest single main being 6½ miles. The gas is sent into these mains at a pressure of 5 pounds per square inch. Each producer when in operation gasifies an average of 20 tons of coal per 24 hours.

There is, of course, a ready market for the chief by-product of this plant—sulphate of ammonia. As previously stated, this amounts to 80 or 90 pounds per ton of coal fired, and brings a return amounting to approximately $2.25 per ton of coal gasified. The tar by-product, which amounts to considerable in a plant of this magnitude, is also

A. SOUTH STAFFORDSHIRE GAS COMPANY'S CENTRAL DISTRIBUTING STATION.



B. ELECTRIC GENERATOR.

sold, and is used for roofing, paving, briquetting, and by the tar distilleries.

The steam required by the plant is generated in Climax boilers. These are so arranged that either coal or producer gas may be used as fuel, or both at the same time if desired.

After passing the centrifugal tar extractors the gas is cleaned by means of a sawdust purifier to insure freedom from tar before turning the gas into the mains, as a plug in the underground pipe lines would be serious. That this method of tar extraction has proved effective is shown by the following statement of the manager of the plant in a recent letter: "Since the plant started four years ago the pressure has never been out of the mains and the supply has never failed."

COKE-OVEN AND BLAST-FURNACE GAS.

One of the most common types of gas producer is the blast furnace. Of course, the blast furnace is not built primarily for gas production, and the gas is simply a by-product. The quantity of gas generated in the ordinary blast furnace is large, and its use for heating purposes and for power development in gas engines has increased rapidly during the past few years, especially since the introduction of the large gas engine.

The heat value of blast-furnace gas is low, averaging about 80 or 90 B. t. u. per cubic foot, but it is an excellent gas for power purposes. Upon leaving the blast furnace the gas is exceedingly dirty, and before passing to the engine requires very thorough washing and cleaning, in order to prevent serious wear in the cylinders and the clogging of the engine passages. The cleaning equipment for such gas is necessarily large and expensive, but even with the high cost of cleaning it is economy to use this by-product, which otherwise would be wasted. Extensive installations of engines operating on blast-furnace gas are found all over Europe and also in the United States. Two of the most notable in this country are those at the Lackawanna Steel Company's plant at Buffalo, N. Y., and the Indiana Steel Company's plant at Gary, Ind. The former installation develops 40,000 horsepower by means of two-cycle gas engines in units of 1,000 and 2,000 horsepower, and the latter consists of 17 units of 2,000-kilowatt rating each and 16 blowing engines of about the same capacity. Six new units of 3,000 kilowatts each have recently been ordered.

Another gas that has been used more or less extensively and successfully abroad and in one or two installations in this country is that from the by-product coke-oven plant; therefore the by-product coke oven, in a sense, may be regarded as a gas producer. This method of gas generation has attracted considerable attention of late, and in the opinion of some will eventually cause extensive installations of large by-product coke-oven plants to be made. It is claimed that by this process the coke produced, which can be used for practically all domestic purposes, will pay costs and that all revenue derived from the sale of gas will be clear profit. Others believe that it will pay to erect such plants for the value of the gas alone, and that the coke will be a profit-making by-product.

GAS DISTRIBUTION.

One of the special advantages of gas, both as a fuel and for use in the gas engine, is the ease with which it may be piped to different portions of a plant. If the gas is properly cleaned and freed from tar, it should cause no trouble in the distributing lines. For local transmission the pressure may be very low (only an ounce or two), thus making the upkeep of the pipe system small, as leaks can be stopped easily. No care is required in the way of insulation, as there is nothing which will condense in the pipes.

The situation is entirely different in the case of steam distribution. Here the pressures are high (100 to 150 pounds per square inch), the repair bill is often excessive, and leaks are a constant source of trouble. Insulation is also required, which adds greatly to the cost, and the methods of pipe laying are necessarily expensive. When steam lines are long and improperly insulated serious losses result from condensation. With steam the pressure in the lines must be high in order that the steam may enter the engine at or a little above the initial pressure required in the cylinder. With gas only enough pressure is required in the distributing lines to insure delivery, and in many cases the gas is below atmospheric pressure and is drawn into the engine by the suction stroke

A large steam engine is usually erected close to the boilers in order to lessen the troubles from condensation, leakage, and the cost of installation. Owing to the ease of gas distribution, gas engines may readily be located at various portions of a plant.

The distribution of producer gas over extended areas is destined to become a considerable enterprise if the possibilities shown by such a plant as that described on page 68 are fully realized. For long-distance transmission of the gas the pressure in the mains is but a few pounds, being only 5 pounds in the plant referred to. This pressure is so low that the upkeep of the pipe line is a very small item.

ARRANGEMENT OF PLANT.

In a great many producer installations little attention apparently has been paid to the proper location and arrangement of the operating rooms. The difficulties that are so noticeable in many steam installations are cropping out in producer-gas plants, especially if they are comparatively small. It is only recently that care in arranging the power end of a manufacturing industry has received proper economic consideration. Unfortunately there seems to be an idea that because economy in fuel utilization is claimed for producer-gas power plants, economy in every other direction must be practiced, even to the extent of sacrificing proper methods of installation and operation. This is an unfortunate attitude and is doing much to seriously interfere with the proper development of producer plants.

One of the primary requisites of producer installations is convenient access to all parts of the plant and perfect freedom in manipulation. Additional room should be allotted wherever necessary for the possible removal of any portion of the plant at any time, and the operating room should be sufficiently large to provide plenty of light and ventilation for the comfort of the operators. This is particularly important in plants of the pressure type, owing to the tendency of the gas to escape into the room. In any type of plant the removal of ash and clinker is always accompanied by more or less dirt and dust, gaseous fumes and heat, and unless proper care is exercised they may prove sufficiently obnoxious to cause not only serious inconvenience to the operator but possibly his resignation. Satisfactory work can not be secured from operators who are required to labor in dark, dirty, cramped quarters.

Additional precaution should be taken to provide proper drainage. Not only is this important from the standpoint of cleanliness, but the wash water from the scrubber is likely at times to contain considerable sulphur and tarry matter, which may serve to clog the pipes and cause serious deterioration unless proper provisions for its disposition have been made.

REQUIREMENTS OF A GOOD PRODUCER.

In suggesting the requirements of a good producer it is deemed wise to utilize directly suggestions of manufacturers. Among these are the following:

1. The quality of the gas should be under control.
2. Clean gas should be assured.
3. There should be no leakage of gas either when the producer is idle or in operation.
4. The gasification should be rapid.
5. All parts of the fuel bed should be easily accessible.
6. A large fuel reservoir should be provided.
7. The level of the fuel bed should, if possible, be kept constant.
8. The producer installation should insure a uniform depth of fuel at all points and uniformity in the rate of gas production.
9. Producers should allow the use of fuels of widely varying quality.
10. The producer installation should give accessibility to the ash bed and proper facility for the removal of the ashes.
11. Producers should have poke holes at the top and sides.
12. All parts of the producer should be easily accessible.
13. Arrangement should be made for the removal of large clinkers.
14. Operating valves should be tight and not affected by dirty gas.

15. All joints should be tight, so that air can not mix with the gas.
16. The vaporizer should be so situated as not to be affected by expansion or contraction.
17. Except in the down-draft type, no air should be admitted while feeding the coal.
18. The quantity of water fed to the vaporizer should be controlled.
19. If possible the steam entering the fuel bed should be superheated.
20. Grates should operate with minimum waste of fuel.
21. The producer should respond to sudden changes of load.
22. The resistance of the fuel bed and cleaning apparatus should be a minimum.
23. The producer should insure ease in operation.
24. The producer installation should insure, when required, continuous service.
25. The working should be continuous, or if shut-downs are necessary, they should occur at long intervals and should be of as short duration as possible.
26. The loss of heat in the producer should be as small as possible.
27. The cost of labor and upkeep should be small.
28. The first cost should be small.

Obviously, at the present stage of development it is impossible to secure a plant meeting all these requirements, and it is questionable whether one without drawbacks will ever be built. In designing or purchasing a plant the points noted above should be considered and the type of plant selected which best meets the major requirements with the least number of objections.

RAPID INTRODUCTION OF GAS-PRODUCER PLANTS.

The use of producer gas for heating and reduction purposes in the iron and steel industries has been more or less general for the past 40 or 50 years and the number of gas-producer installations in connection with these industries has increased steadily from the first. During the past decade, however, unusual interest has been taken in the adaptation of producer gas to metallurgical work and to-day practically all the modern steel plants depend largely upon it in an extensive variety of applications, including its use for power generation.

Although the development of the gas producer for heating and reduction purposes in the metallurgical and allied industries has of late been very rapid, the increase in the number of producer-gas power plants has been even more marked. Definite figures regarding the number of installations for heating and metallurgical purposes are not available, but special efforts have been made to secure a fairly complete list of producer-gas power plants in the United States. Such a list was prepared during the summer of 1909 and published in Bulletin 416[a] of the United States Geological Survey, covering the recent development of the producer-gas power plant in the United States. So interesting are the summaries and diagrams prepared from this extensive list that they are again presented in this report, as they indicate in concise form the rate of growth during the past decade and the general character of probably 85 per cent of the installations used for power purposes in the United States in 1909. Figures 11 and 12 show the annual increase, both in number and in horsepower, of the producer-gas power plants operating on anthracite, bituminous coal, and lignite.

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[a] Reprinted as Bureau of Mines Bulletin 9, 1911.

The work of the Survey began in 1904 with a systematic investigation of the possible use of bituminous coals, lignite, and peat for generating producer gas for power purposes. A study of Figures 11 and 12 shows clearly the marked increased in the number of plants and in the horsepower of such installations since the beginning of these researches.

One of the fundamental reasons for this rapid development is the low fuel consumption of these plants per horsepower-hour. This consumption varies considerably with the heat value of the fuel, but the St. Louis tests show that even for the low-grade fuels the relative consumption is low, as indicated in figure 13.

At the time the list reported in Bulletin 416 was compiled (June, 1909) there were over 500 power plants of this character in operation in the United States, ranging in size from 15 to 6,000 horsepower. Data secured from this list are summarized in the following table according to the type of fuel used and the capacity of the plant.

It will be observed from this table that about 88 per cent of the total installations in this country are operating on anthracite (a few using charcoal or coke), and that bituminous coal and lignite are used in the remaining 12 per cent. Of the total horsepower approximately 57 per cent is derived from bituminous coal and lignite and 43 per cent from anthracite, charcoal, and coke. In point of size it will be noted that the plants using bituminous coal average twelve and one-half times the size of those using anthracite.

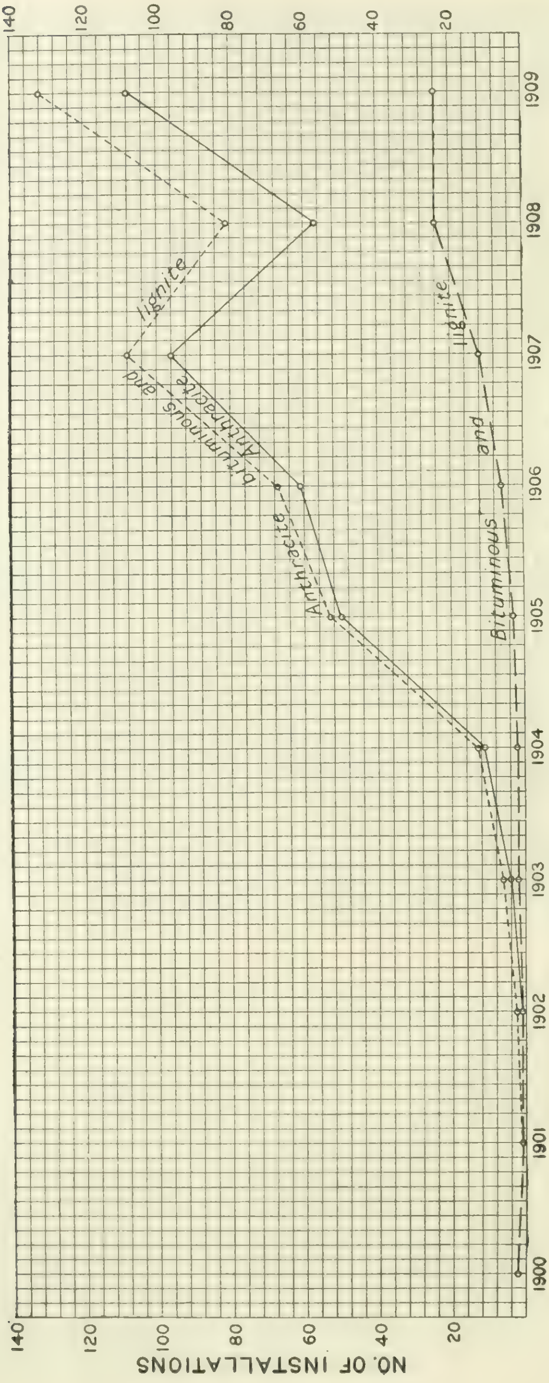

FIGURE 11.—Annual increase in number of producer-gas power plants in the United States.

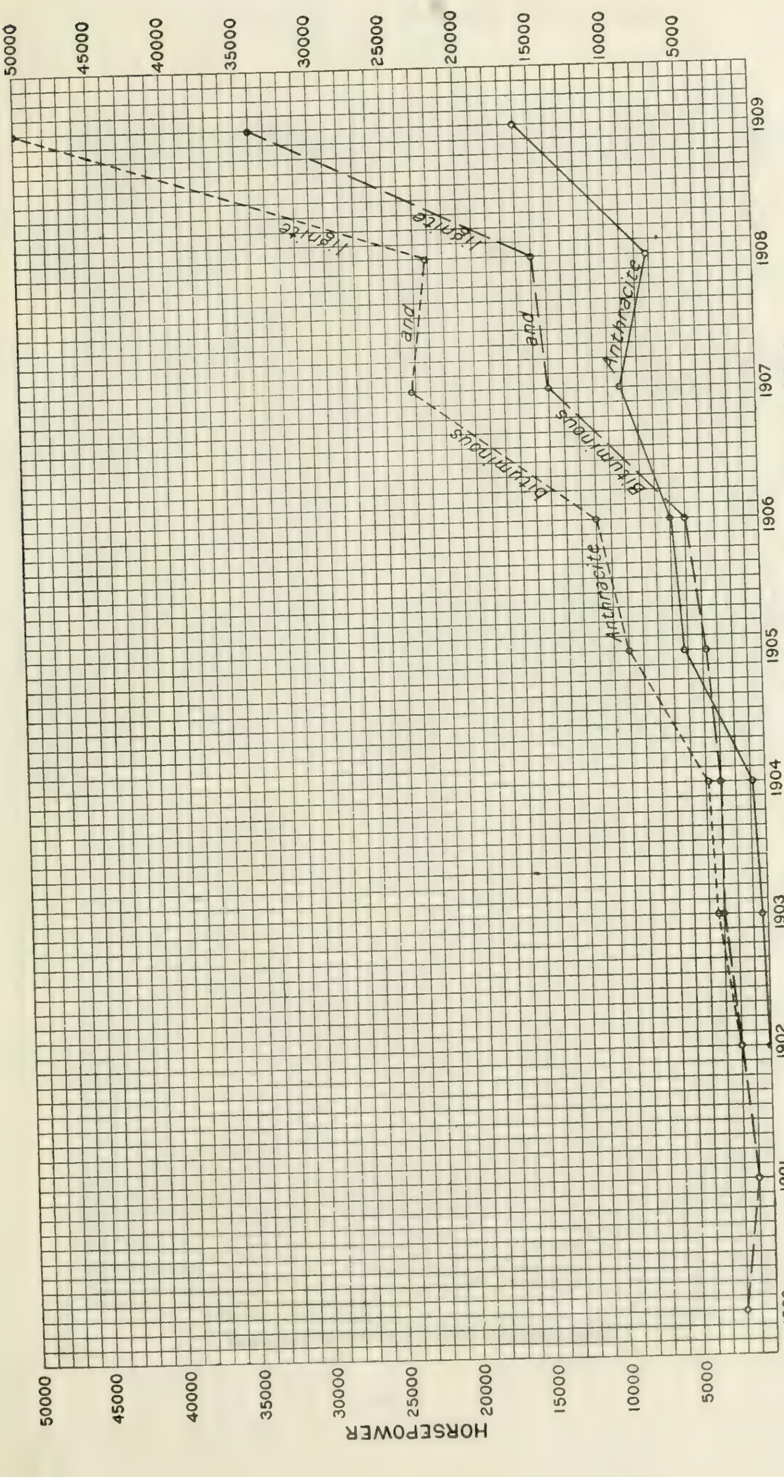

FIGURE 12.—Annual increase in total horsepower of producer-gas power plants in the United States.

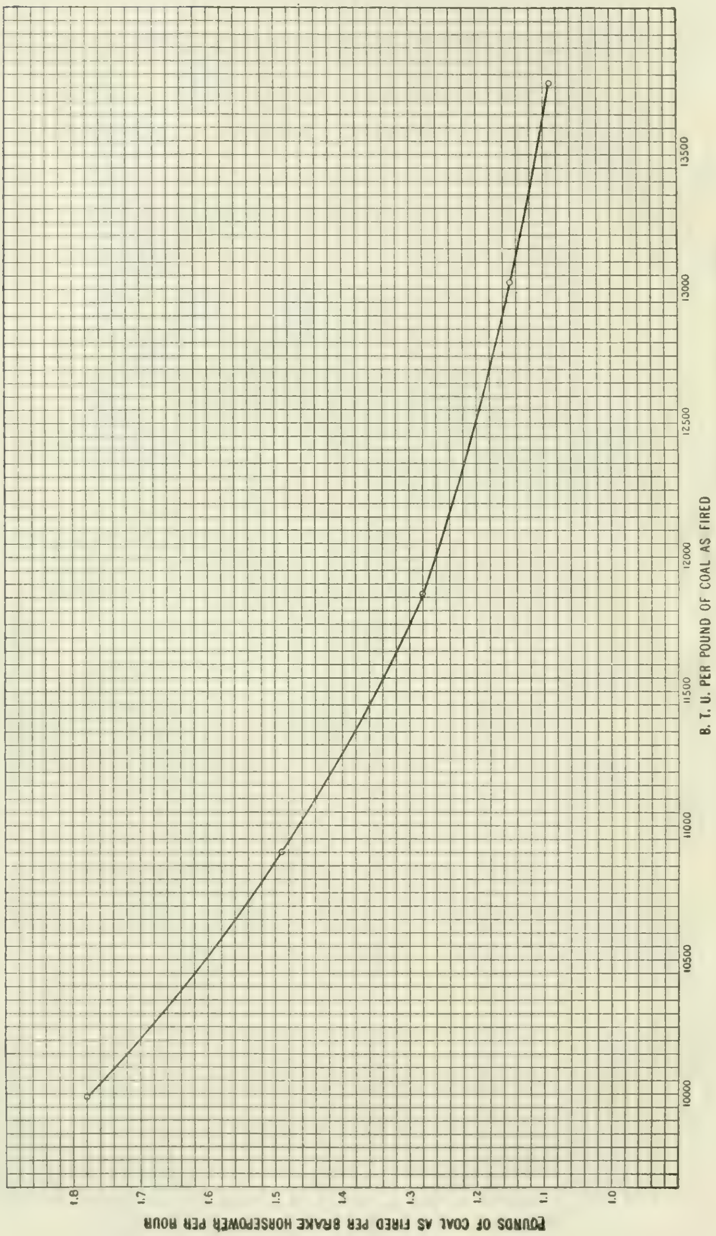

FIGURE 13.—Relation of the weight of coal used per horsepower-hour to calorific power of fuel.

Tabulation of producer-gas power plants in the United States according to capacity and kind of fuel used.

Character of fuel and capacity of plant.	Number of plants.	Horsepower.				Per cent of total plants.	Per cent of horsepower.
		Total.	Average.	Minimum.	Maximum.		
Anthracite:							
Over 500 horsepower	8	7,550	950	600	1,500	....	....
500 horsepower or less	407	40,550	100	15	500	....	....
	415	48,100	116	15	1,500	88	43
Bituminous coal:							
Over 500 horsepower	20	49,000	2,450	750	6,000	....	....
500 horsepower or less	17	5,150	300	35	500	....	....
	37	54,150	1,460	35	6,000	8	49
Lignite:							
Over 500 horsepower	3	7,275	2,430	525	3,750	....	....
500 horsepower or less	19	1,725	90	25	250	....	....
	22	9,000	410	25	3,750	4	8
All plants	474	111,250	235	15	6,000	100	100

Personal inspection of a large number of these installations has shown (1) that the plants as a whole are giving remarkable satisfaction considering the brief period of development since the introduction of this type of power, (2) that the most serious difficulty seems to arise from a lack of competent operators to run the plants rather than from defects or troubles inherent in the plants themselves.

PART II.

REPORTS OF INVESTIGATIONS AT ST. LOUIS AND NORFOLK.

By R. H. Fernald and C. D. Smith.

INTRODUCTION.

It was realized by the committee in charge of the producer-gas investigations at St. Louis in 1904 that up to that time practically no bituminous coals, lignites, or peats had been utilized in gas-producer installations for power development. The scope of the work as specified by Congress, therefore, was construed to cover investigations relating to the commercial possibilities of a wide range of fuels in gas-producer plants rather than to the study of the fundamental thermodynamics, and chemical and physical laws of producer-gas generation. Accordingly, arrangements were made for securing a large variety of samples from the principal fuel-producing areas of the United States. Considered commercially and economically the results of the investigations were eminently satisfactory.

Attention should be directed, however, to the fact that the conditions imposed prohibited a length of test on each fuel which would make it possible to guarantee the accuracy of some of the detailed results. The amount of coal supplied from each mine was usually one carload. Mine owners frequently desired a variety of tests upon each sample of fuel to determine its possibilities under the steam boiler, in the gas producer, in the briqueting plant, and in the coking oven. Under such conditions it was usually possible to obtain only 15 or 20 tons for the gas-producer plant. With the producer used, a sample of this size was only large enough for a test of 50 or 60 hours' duration.

Subsequent investigations have shown that for a plant of the size used guaranteed results in the way of coal consumption per horsepower hour can be obtained only after operating about 100 hours or more. Therefore the consumption and efficiencies reported for the St. Louis tests may be slightly in error, but this has no direct effect upon the main results of the investigations, as the possibilities of successfully utilizing a wide range of fuels in producer-gas installations for power development were conclusively proved.

In the Norfolk investigations larger samples of the individual fuels were obtained, and a more critical study was made of the relation of the length of test to the accuracy of the detailed results. (See Bull. 393, U. S. Geol. Survey.)

PERSONNEL.

The tests were outlined and supervised by R. H. Fernald, engineer in charge of producer-gas tests.

At St. Louis the work was performed under the direction of J. A. Laird (October, 1904, to November, 1906), C. O. Nordensson (November and December, 1906), and J. P. Quam (December, 1906, to February, 1907), and by C. W. Lummis, J. G. Culbertson, R. W. Cummings, H. G. Ecker, H. A. Grine, M. H. Mount, R. E. Peshak, Kurt Toensfeldt, W. C. Weidmann, C. A. Gilmore, John Laichinger, C. D. Smith, F. V. Roy, Curt Adler, W. B. Lemmon, John Sutor, C. L. Armstrong, Lauson Stone, J. G. Goodwin, W. L. Hempelmann, D. A. Barkley, J. K. Black, L. A. Delano, S. P. Howell, Julian Teza, W. J. Harris, jr., E. C. Herrling, A. B. Bridgeman, H. C. Austin, and D. F. Smith.

The tests made at Norfolk were outlined by R. H. Fernald, and the work was performed, under the direction of D. T. Randall, by the following assistants: C. D. Smith, John Sutor, H. A. Grine, W. B. Lemmon, D. F. Smith, C. G. Adler, J. C. Barnaby, J. K. Black, H. M. Cooper, D. A. Barkley, A. B. Plummer, G. C. Faville, jr., W. H. Doyle, and Grover Sykes. All computations were made by Lauson Stone, S. P. Howell, and R. S. Scott. During the construction period the following men were also employed for a few months: J. P. Quam, F. H. Vose, John Laichinger, J. E. Olivenbaum, C. E. Herrling, W. J. Harris, jr., and L. C. Hopkins.

EQUIPMENT.

THE ST. LOUIS PLANT.

A general description of the plant employed for the tests at St. Louis has been presented under the head of pressure-producer plants in Part I, pages 21–26. In the original installation one producer and one economizer were used, but to facilitate the work a second producer and a second economizer were added before renewing the testing operations in May, 1905. The plant at that time consisted of two independent producers, both discharging into the same scrubber. These producers were worked independently, one being charged while the other was in operation. By this arrangement no time was lost in the tests, as a simple manipulation of valves brought the second producer into operation as soon as the first was cut out. The details of the installation are shown in figures 3 and 4 (pp. 23, 24).

The first gas generator installed had a rated capacity of 250 horsepower, and is designated producer No. 7. The later addition was a 350-horsepower generator known as producer No. 8, which was operated upon anthracite during the exposition period as an exhibit in the power house of the Louisiana Purchase Exposition Co. This generator was lined with an extra heavy layer of fire brick to make the internal diameter correspond to that of the 250-horsepower generator.

As the majority of coals tested ran high in sulphur—in one case over 8 per cent—the original purifying equipment proved of little value, and at the time the additional installation was made a second purifier was added. This second purifier was deemed necessary, as experience had shown that a single purifier was not sufficient to remove the sulphur from gas generated from coals containing much over 1 per cent of that substance. The two purifiers were so arranged that they could be operated either singly or in series, as shown in figure 4. The addition of a second purifier produced no marked improvement, and after a few weeks of unsatisfactory use the entire purifying system was discarded and the gas with its full charge of sulphur was allowed to enter the engine cylinders. There were no other changes in the operating portion of the plant so far as new installations were concerned, although several changes in detail were made from time to time as the nature of the work demanded.

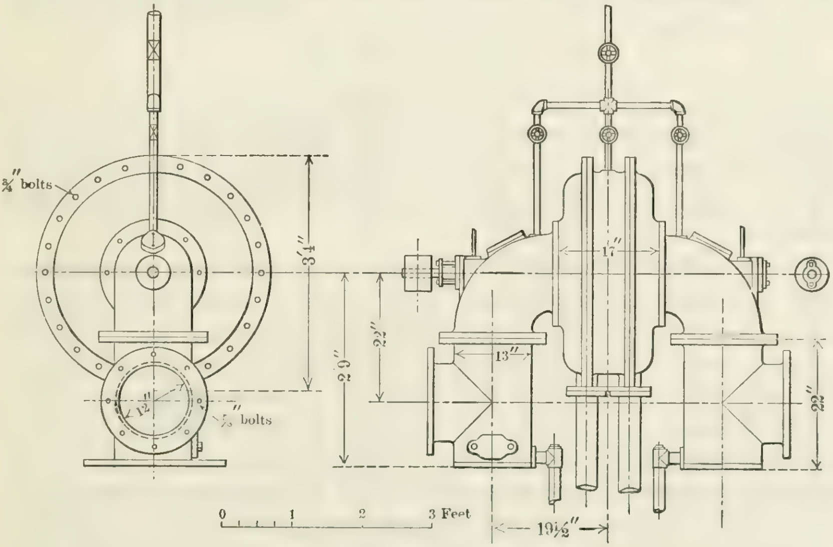

FIGURE 14.—Centrifugal tar extractor.

The centrifugal tar extractor used in connection with this plant proved to be very efficient when properly handled. This extractor, end and side views of which are shown in figure 14, was driven by a 10-horsepower electric motor.

When the plant was first installed the scrubber was filled with coke, according to the usual custom. During test No. 39 it was noted that the gas did not flow freely through the scrubber, and this trouble finally became so serious that the test had to be discontinued.

The coke was removed from the scrubber and was found to be entirely filled and coated with tarry matter. A supply of old bricks was available, and as an experiment these bricks were substituted for the coke. In putting the bricks into the scrubber no attempt was made to arrange them according to any system. They were simply thrown in, and the irregular pile thus formed allowed ample space for the flow of gas and water, and at the same time the spacing was sufficiently irregular to bring the gas and water into intimate contact. This brick filling served very satisfactorily from July, 1905, until the close of the testing work in St. Louis in 1907, although at the time of dismantling the plant for transfer to Norfolk it was found that there was a core of tarry matter and brick through which no gas could flow. This core, although about 2 feet in diameter, was not of sufficient size to seriously interfere with the regular functions of the scrubber.

THE NORFOLK PLANT.

The producer-gas power plant installed at the fuel-testing station erected at Norfolk in 1907 consisted for the most part of the same apparatus that was used in the plant at St. Louis.[a] A small auxiliary boiler was added, however, and a part of the original equipment was discarded.

Figure 15 shows the plan of the plant, as well as the general arrangement and principal dimensions. Figures 16, 17, and 18 show elevations. As long tests were contemplated, a water seal was provided through which ashes could be removed without interfering in any way with the operation of the producer. This arrangement, illustrated in figures 19 and 20, gave satisfaction, although the producer was not designed for a water seal. Figure 20 also gives a section of the entire producer, and shows the holes in the producer shell and fire-brick lining through which temperature measurements of the fuel bed were made, and by means of which gas samples for analysis were taken.

The economizers,[b] although not used as such, were installed with the producers. They had their inner flues or tubes removed, and large gas pipes from the bottom of the economizers completed the connection between the producers and the scrubber, as shown in figure 15.

Instead of filling the scrubber with coke, as is the usual practice, it was filled about two-thirds full of old bricks; these, however, were not thrown in promiscuously, as in the St. Louis plant, but were placed on edge, checkerwork style, with spaces of about an inch between them. The usual spray of water was provided at the top, and from all indications the results were as satisfactory as when coke is used.[c]

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[a] For a description of the St. Louis plant, see pp. 21–26.

[b] For description of the economizer, see p. 25.

[c] For description of the scrubber, see pp. 25–26.

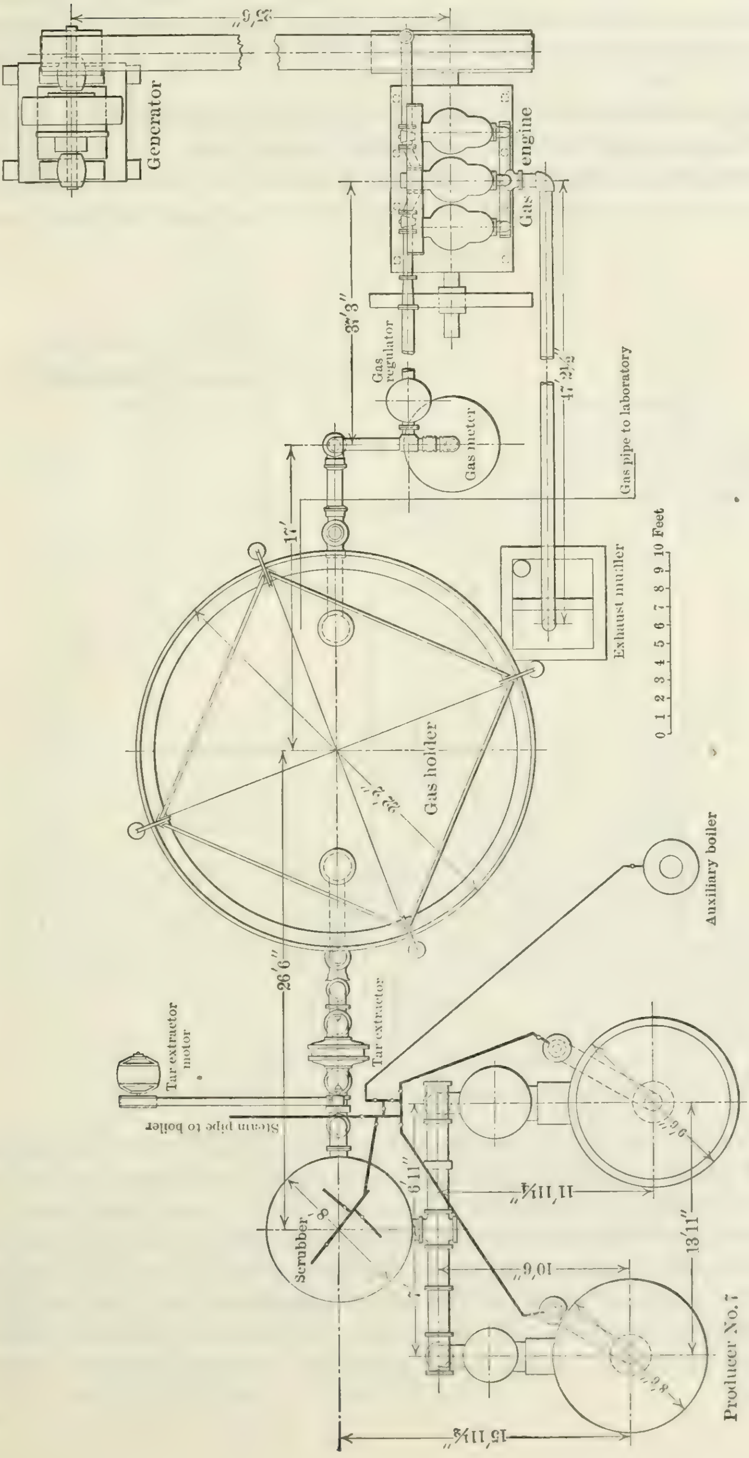


FIGURE 15.—Plan of producer-gas plant at Norfolk.

From the scrubber the gas went through a centrifugal tar extractor driven by a 10-horsepower motor. From the tar extractor the gas passed directly into a gas holder having a capacity of 4,000 cubic feet.

The purifier installed in the St. Louis plant between the tar extractor and the gas holder was omitted in the Norfolk plant. The purpose of the purifier is to absorb any sulphur that may be present in the gas, but inasmuch as the purifier furnished with this plant had been found inadequate and the St. Louis tests had demonstrated that the sulphur in the gas produced no injurious effect upon the engine, the purifier was not moved to Norfolk with the rest of the St. Louis installation.

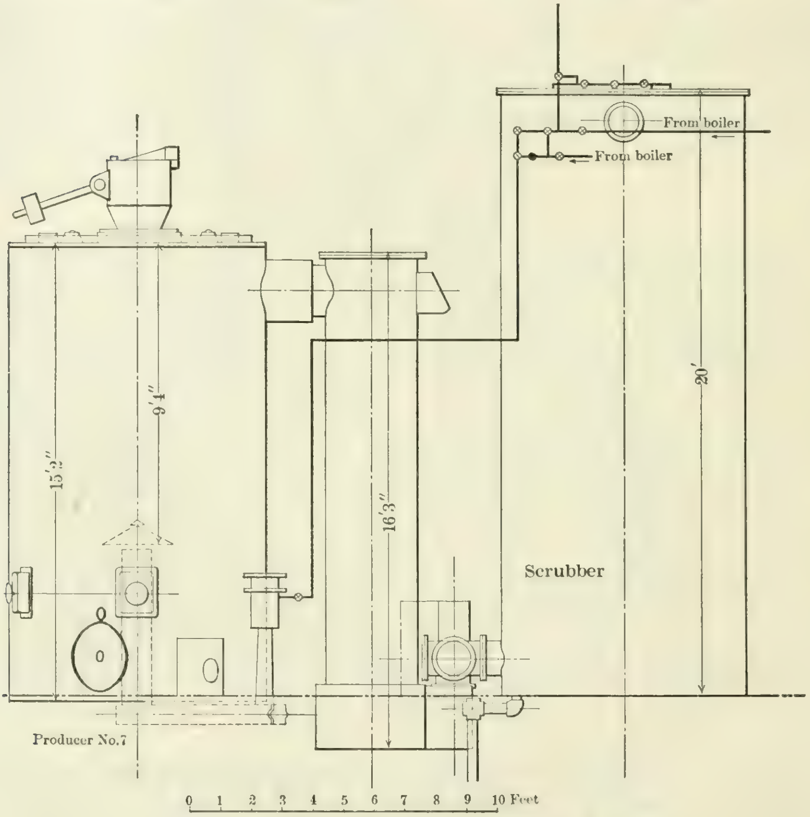


FIGURE 16.—Elevation of gas producer No. 7, Norfolk plant.

After passing through a meter having a capacity of 30,000 cubic feet per hour, the gas was delivered to a three-cylinder vertical Westinghouse gas engine, rated at 235 brake horsepower on producer gas. The engine was belted to a six-pole 200-kilowatt Bullock direct-current generator, as indicated in figure 15, and shown on Plate VII,*B*.

The load on the electric generator was controlled by a water rheostat, shown in Plate VIII, *A*. The generator, however, supplied power to several motors pertaining to the plant, but by means of the water rheostat the load on the gas engine, shown in Plate VIII, *B*, was kept fairly uniform regardless of excessive motor-load variations.

The engine exhaust was muffled by passing it through a concrete expansion chamber buried in the ground and covered with about 1 foot of earth. This gave such excellent satisfaction that it is shown in detail in figure 21. The outlet from the expansion chamber was an ordinary 12-inch smokestack, about 15 feet in height. This arrangement made the engine exhaust barely audible. On several occasions heavy explosions occurred in the muffler, but the only effect was to raise or slightly displace the concrete cover.

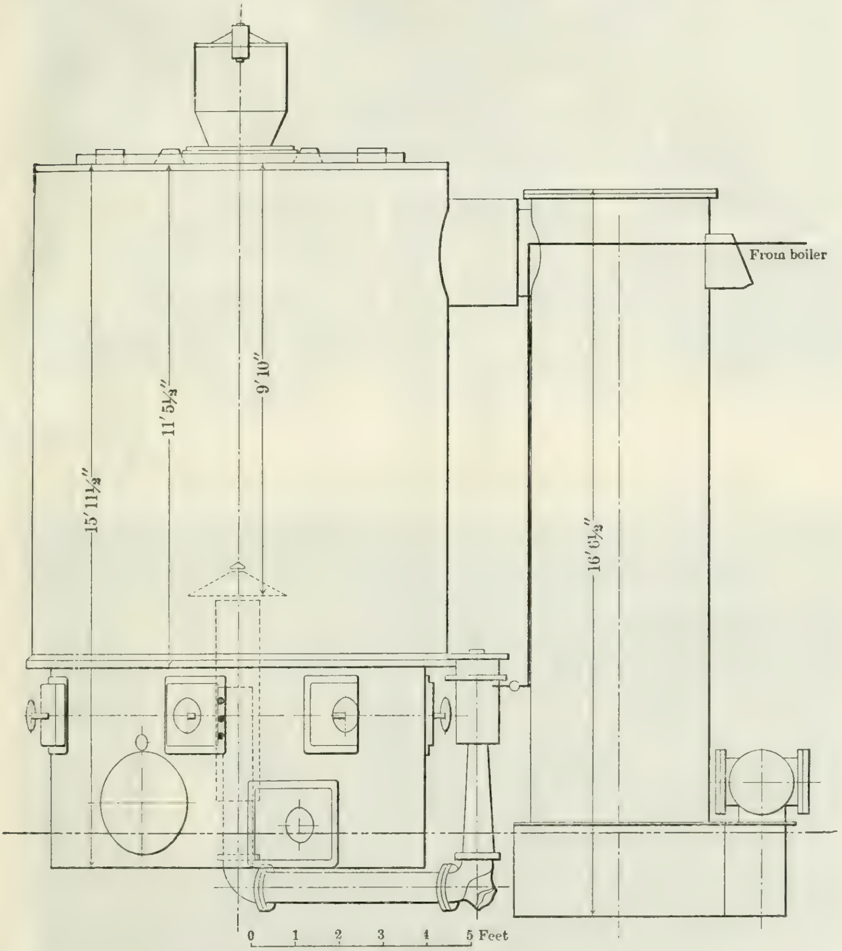


FIGURE 17.—Elevation of gas producer No. 8, Norfolk plant.

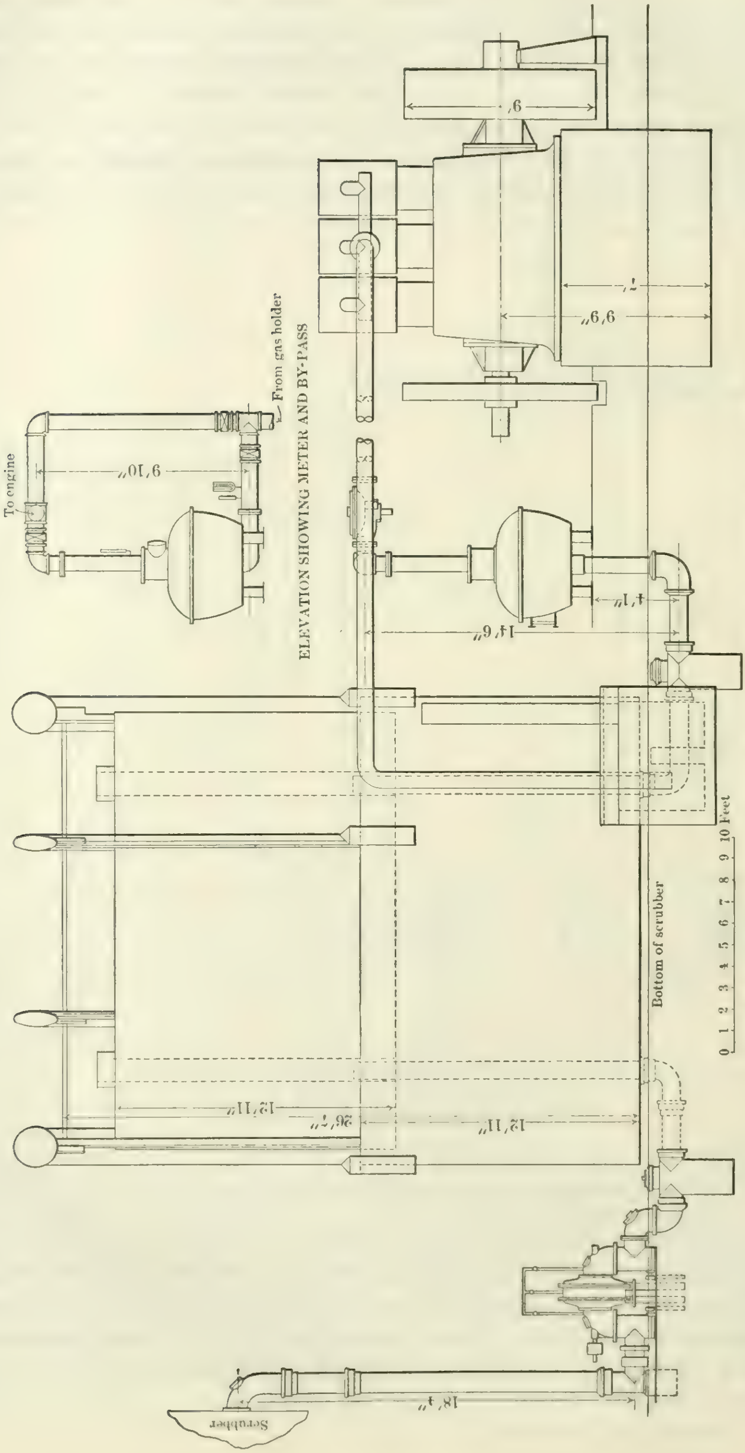
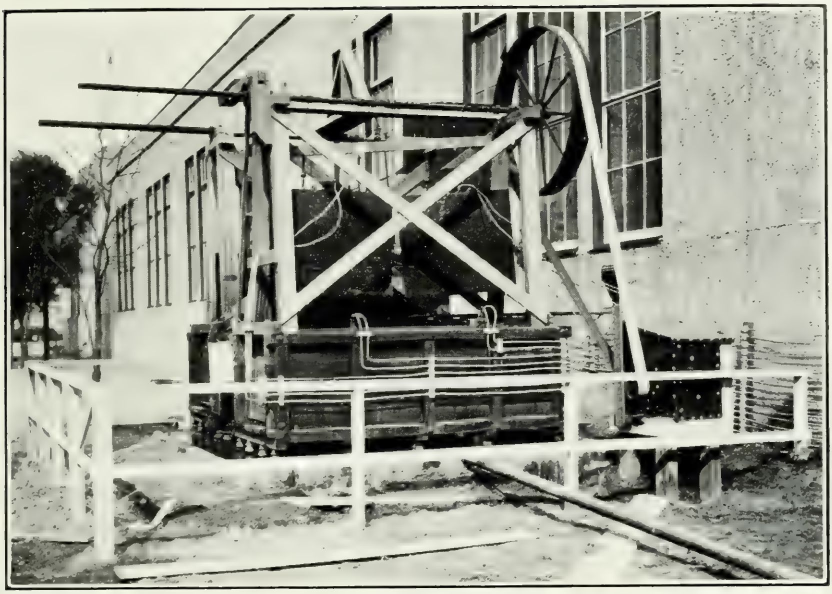
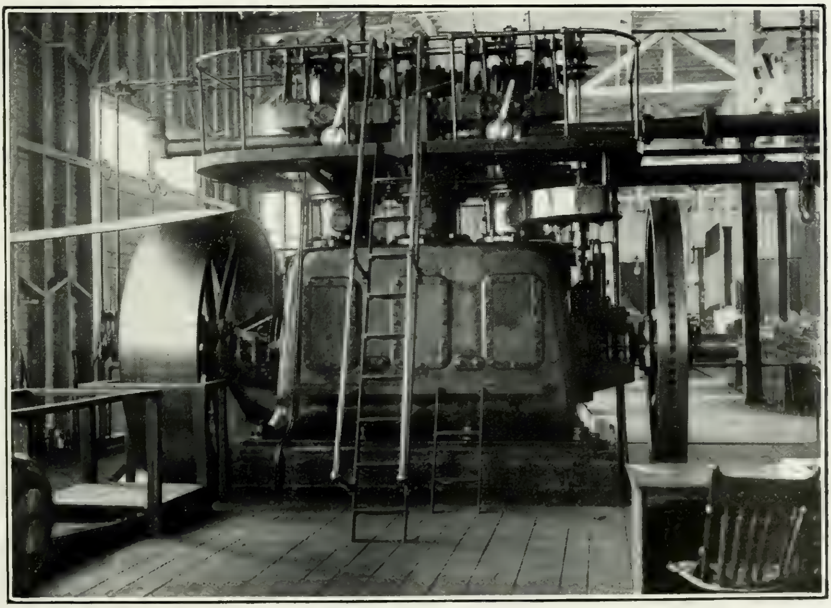


FIGURE 18.—Elevation of tar extractor, gas tank, meter, and engine, Norfolk plant.



A. WATER RHEOSTAT.



B. THREE-CYLINDER GAS ENGINE.

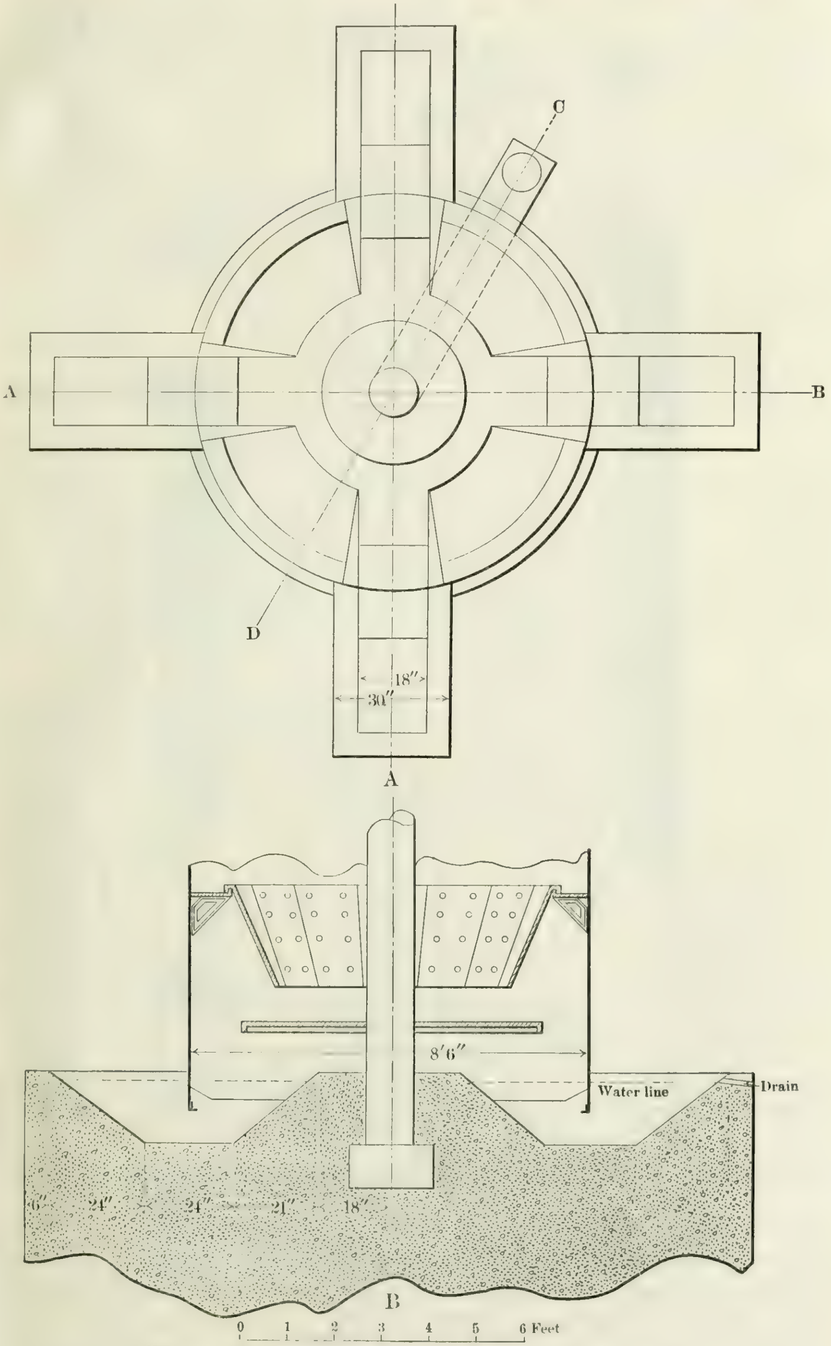


FIGURE 19.—A, plan of water seal; B, cross section of water seal.

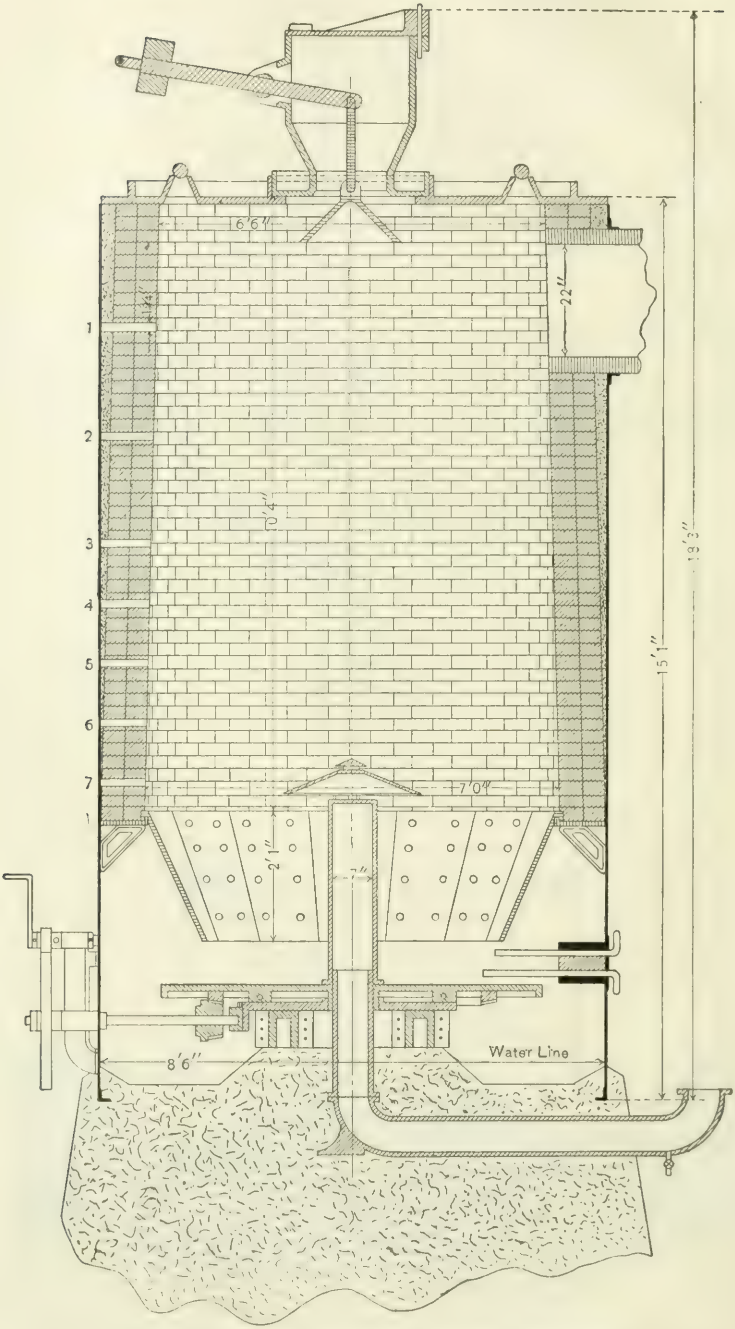


FIGURE 20.—Vertical section of producer showing water seal and holes in the shell for temperature measurements.

The charging floor of the gas producers was arranged especially for ease in operation, and with reference to convenience in reading water meters, manometers, and other instruments, as indicated by Plate IX, *A*.

In order to determine accurately the amount of steam used by the producer, as well as the amount of coal required to generate this steam, a small upright boiler of about 15-horsepower capacity was installed. During the producer-gas tests this boiler supplied the steam necessary for the operation of the gas generator. All coal and water used were weighed, and in order to prevent an error in the figures on steam consumption care was taken to prevent the steam from rising to the blow-off pressure. The regular producer stokers tended this auxiliary boiler with little inconvenience.

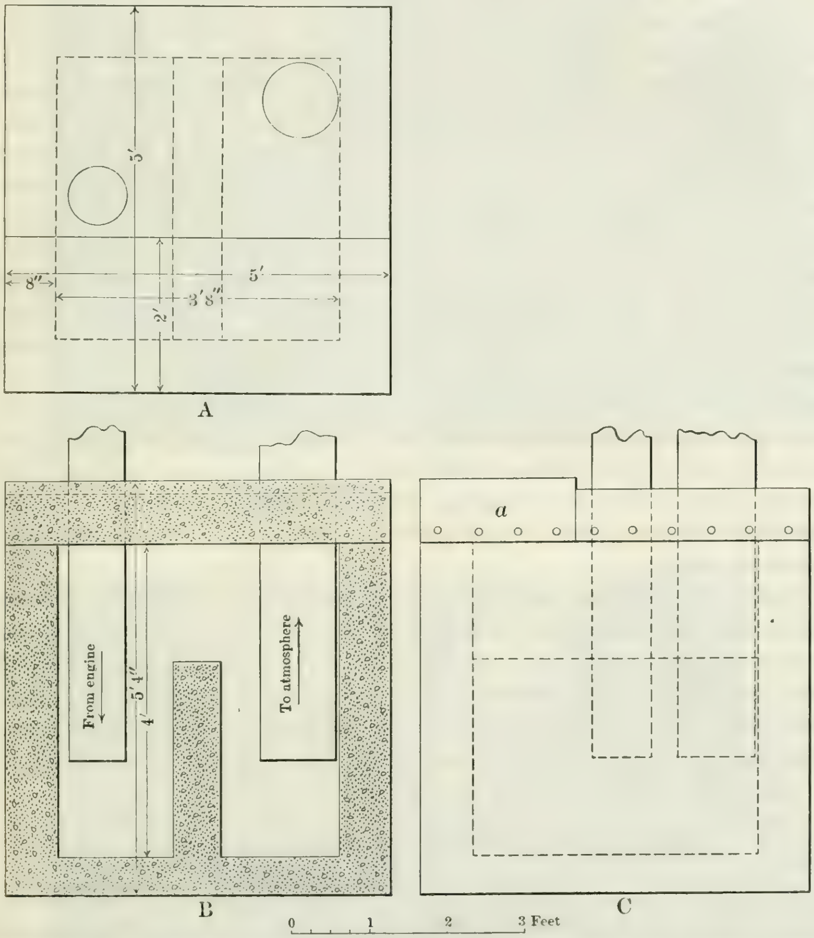


FIGURE 21.—A, plan of exhaust muffler; B, section of exhaust muffler; C, end view of exhaust muffler.

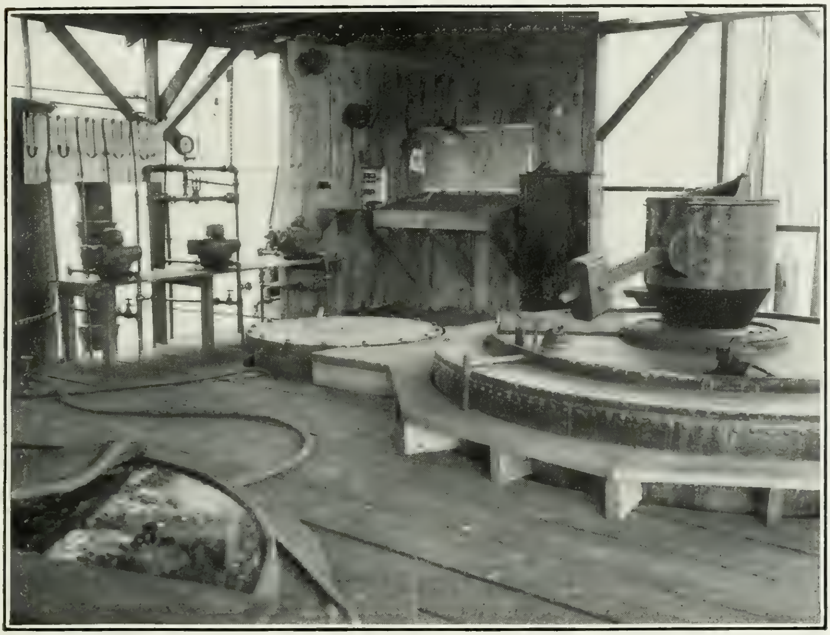
Plate IX, *B*, gives a view of the gas analysis laboratory. A complete analysis of the gas was made every two hours, and at 20-minute intervals a determination of the calorific value of the gas was made with a Junker calorimeter. The heat value of the gas, as reported in this bulletin, is based on the high readings of the calorimeter.

The water supply for the plant was variable and somewhat uncertain, and was responsible for numerous irregularities in operation. Connection was made with the city water mains at the exposition grounds, but the supply from this source was limited, and from time to time the pressure was so low that it was impossible to get a sufficient quantity of water for the gas-engine jackets. Time and funds were too limited to warrant the installation of an adequate water system, but, to supplement the city supply, two wells, 2 and 4 inches in diameter respectively, were driven to a depth of about 70 feet, and from these additional water was obtained. The two wells were connected to a motor-driven centrifugal pump, which delivered the water to a small settling tank, made necessary by the fine sand and shells which came from the wells. The settling tank was connected to a steam pump which delivered the water, at a pressure of about 25 pounds per square inch, to the pipe line supplying the plant. This arrangement gave absolutely no reserve, and if the pumps stopped the water supply was cut off. Connections with the city mains were accordingly left intact, so that in case the pumps failed the simple turning of a valve would provide a partial if not sufficient supply until the pumps were again in service.

The water meters used were all of the piston type, and were so installed that they could be readily calibrated at any time. The gas meter was examined and carefully repaired before being installed, and from time to time it was calibrated by means of the 4,000-cubic-foot gas holder. The scales used for weighing coal and water were frequently checked with standard weights. The switchboard instruments were calibrated by the Bureau of Standards.

LOG ITEMS AND LOG AND REPORT FORMS.

In order to show in detail the log items, the log-sheet forms, and the method of recording observations, the complete log for one shift of test No. 176 is presented. The forms used in computing and reporting the tests are likewise illustrated by the report and computations for the same run. Because of a rearrangement of the items in the final tabulated results given on pages 272 to 313 and 352 to 358 the item numbers do not necessarily correspond to the item numbers on the computation and report forms here presented. The forms here shown represent those used during the Pittsburg tests, although they were somewhat modified to meet the requirements of the new



A. CHARGING FLOOR OF PRODUCER-GAS PLANT AT NORFOLK.

B. GAS-ANALYSIS LABORATORY AT NORFOLK PRODUCER-GAS PLANT.

equipment of the Pittsburg plant, and they show in general the observations made and forms used throughout the tests at St. Louis and Norfolk.

GAS-PRODUCER LOG.

Recorded by Woodman, Snyder, Billings.

Test No. 176.
Date: Feb. 10–11, 1909.
Time: 8.30 a. m. to 8.30 a. m.

Time.	Temperature (deg. F.).						Pressure (in. of water).					Water.			
	Cold junction of thermocouple.	Air entering economizer.	Air and vapor entering producer.	Gas—			Air and vapor entering producer.	Gas—				Producer.		Wet scrubber.	
				Leaving producer.	Leaving economizer.	Leaving wet scrubber.		Leaving producer.	Leaving economizer.	Leaving wet scrubber.	Entering dry scrubber.	By tank.	Used (pounds).	By meter.	Used (cubic feet).
				° *C.*	° *F.*							*33*			
9 a. m...	148	69	370	620	530	53	−0.10	− 2.9	− 3.0	− 9.1	+4.7	75	42	101639	123
10 a. m...	140	66	355	620	520	51	− .10	− 6.2	− 6.3	−12.7	+4.9	126	51	789	150
11 a. m...	136	64	350	620	500	47	− .10	− 7.0	− 7.1	−13.1	+4.8	180–0	54	943	154
12 a. m...	136	78	355	610	510	49	− .10	− 6.4	− 6.5	−12.9	+5.1	44	44	2098	155
1 p. m...	130	81	350	610	475	52	− .05	− 5.8	− 5.9	−10.8	+4.7	92	48	262	164
2 p. m...	135	79	360	600	520	51	− .10	− 6.3	− 6.3	−13.1	+5.0	139	47	418	156
3 p. m...	139	83	355	610	525	52	− .10	− 9.0	− 9.1	−15.6	+5.1	190–0	51	580	162
4 p. m...	142	78	355	630	525	52	− .10	− 2.9	− 3.0	− 9.3	+5.1	49	49	102742	162
5 p. m...	138	86	365	630	545	51	− .10	− 6.6	− 6.9	−13.7	+5.2	101	52	102905	163
6 p. m...	140	82	370	640	545	50	− .10	− 8.1	− 8.2	−15.0	+5.2	149–0	48	3069	164
7 p. m...	142	80	370	640	535	49	− .15	− 9.5	− 9.7	−16.4	+5.2	44	44	223	154
8 p. m...	142	80	375	640	550	48	− .10	−10.3	−11.0	−21.2	+5.2	90	46	371	148
9 p. m...	142	79	370	640	550	50	− .10	− 3.0	− 3.2	− 9.4	+4.9	135	45	521	150
10 p. m...	142	80	365	630	545	50	− .10	− 6.1	− 6.3	−13.0	+5.2	178–0	43	666	145
11 p. m...	140	80	365	630	535	50	− .10	− 8.3	− 8.4	−15.5	+5.2	47	47	812	146
12 p. m...	136	80	370	650	545	48	− .10	− 4.0	− 4.3	−11.7	+5.4	103	56	103963	151
1 a. m...	140	80	380	660	550	49	− .10	−20.4	−20.5	−27.2	+5.0	145	42	104115	152
2 a. m...	142	82	380	650	580	50	− .10	−11.4	−13.7	−16.0	+5.3	197–0	52	263	148
3 a. m...	145	84	380	680	570	50	− .10	− 4.7	− 4.8	−10.1	+5.0	29	29	404	141
4 a. m...	146	81	375	650	550	50	− .10	−10.8	−10.9	−17.3	+5.3	103	74	555	151
5 a. m...	148	93	370	640	555	49	− .10	− 9.2	− 9.4	−16.0	+5.2	170–0	67	703	148
6 a. m...	146	82	375	640	560	50	− .10	−12.4	−13.1	−19.6	+5.3	40	40	847	144
7 a. m...	143	94	370	650	570	52	− .10	−14.4	−14.8	−21.6	+5.4	103	63	995	148
8 a. m...	143	85	375	660	565	51	− .10	−11.8	−11.9	−18.3	+5.4	172	69	105139	144

FUEL RECORD.

Recorded by E. J. Billings.

Test No. 176.
Date: Feb. 10, 1909.
Time: 12.30 a. m. to 8.30 a. m.

Time.	Weight of box and fuel delivered to scales (pounds).	Weight of box and fuel after each firing (pounds).	Fuel fired each time (pounds).	Time.	Weight of box and fuel delivered to scales (pounds).	Weight of box and fuel after each firing (pounds).	Fuel fired each time (pounds).
12.35 a. m..........	332.0	285	47	4.10 a. m..........	....	207	33
12.55 a. m..........	....	245	40	4.20 a. m..........	....	147.0	60
1.15 a. m..........	....	211	34	4.50 a. m..........	647.0	609	38
1.25 a. m..........	....	147.0	64	5.05 a. m..........	....	580	29
1.40 a. m..........	647.0	610	37	5.25 a. m..........	....	553	27
2.05 a. m..........	....	538	72	5.45 a. m..........	....	516	37
2.18 a. m..........	....	511	27	6.03 a. m..........	....	409	107
2.30 a. m..........	....	493	18	6.20 a. m..........	....	378	31
2.40 a. m..........	....	455	38	6.40 a. m..........	....	337	41
2.50 a. m..........	....	424	31	6.50 a. m..........	....	277	60
3.10 a. m..........	....	392	32	7.10 a. m..........	....	235	42
3.20 a. m..........	....	361	31	7.30 a. m..........	....	187	48
3.30 a. m..........	....	335	26	7.40 a. m..........	....	147.0	40
3.40 a. m..........	....	300	35	8.03 a. m..........	147.0	600	47
3.48 a. m..........	....	270	30	8.15 a. m..........	....	541	59
3.57 a. m..........	....	240	30				

GAS-ENGINE LOG.

Recorded by A. J. Hazlewood.

Test No. 176.
Date: Feb. 10, 1909.
Time: 12.30 a. m. to 8.30 a. m.

Time.	Revolutions.		Pressure.			Gas.			Jacket water.			
			Manometer (in. of water).		Barometer (in. of mercury).	Temp. at meter (deg. F.).	Cubic feet.		Temperature (deg. F.).			
	By counter.	Increment.	Entering gas meter.	Leaving gas meter.			By meter.	Used.	Entering.	Leaving.	By meter.	Used.
12.40 a. m.			4.0	2.4		61	139362250	4150	38	136		
1.00 a. m.	195560	7960	3.8	2.3		61	66500	4250	38	140	303315	74
1.20 a. m.			3.6	2.1		61	70790	4290	38	138		
1.40 a. m.			3.9	2.4		61	75080	4290	38	135		
2.00 a. m.	203508	7948	3.8	2.3		62	79330	4250	38	141	3391	76
2.20 a. m.			3.6	2.1		62	83610	4280	38	142		
2.40 a. m.			3.5	2.0		62	88160	4550	38	144		
3.00 a. m.	211470	7962	3.7	2.1		62	92650	4490	38	142	3468	77
3.20 a. m.			3.8	2.3		62	97130	4480	38	141		
3.40 a. m.			3.5	2.0		62	01480	4350	38	134		
4.00 a. m.	219432	7962	3.6	2.1		62	05890	4410	38	136	3546	78
4.20 a. m.			3.8	2.3		61	10270	4380	38	140		
4.40 a. m.			3.8	2.3		60	14680	4410	38	138		
5.00 a. m.	227386	7954	3.8	2.3		59	19130	4450	38	135	3626	80
5.20 a. m.			3.8	2.2		58	23680	4550	38	138		
5.40 a. m.			3.5	2.0		58	28250	4570	38	137		
6.00 a. m.	235322	7936	3.6	2.1		57	32570	4320	38	140	3704	78
6.20 a. m.			3.6	2.1		57	36840	4270	38	137		
6.40 a. m.			3.6	2.1		56	41020	4180	38	138		
7.00 a. m.	243287	7965	3.5	2.1		55	45210	4190	38	137	3781	77
7.20 a. m.			3.6	2.1		54	49640	4430	38	134		
7.40 a. m.			3.6	2.1		54	53780	4140	38	140		
8.00 a. m.	251245	7958	3.6	2.1		53	57820	4040	38	140	303855	74
8.20 a. m.			3.9	2.5		53	139461900	4080	38	143		

SWITCHBOARD LOG.

Recorded by A. J. Hazlewood.

Test No. 176.
Date: Feb. 10, 1909.
Time: 12.30 a. m. to 8.30 a. m.

Time.	Load.					
	Generator.				Auxiliary motor (watts).	
	Volts.	Amperes.	Watts.		By meter.	Used.
			By meter.	Output.		
12.40 a. m.	227	425				
1.00 a. m.	226	425			5338580	300
1.20 a. m.	225	425				
1.40 a. m.	226	425				
2.00 a. m.	226	425			8850	270
2.20 a. m.	225	425				
2.40 a. m.	227	425				
3.00 a. m.	226	425			9090	240
3.20 a. m.	228	425				
3.40 a. m.	226	425				
4.00 a. m.	227	425			9330	240
4.20 a. m.	228	425				
4.40 a. m.	227	425				
5.00 a. m.	227	425			9580	250
5.20 a. m.	226	425				
5.40 a. m.	228	425				
6.00 a. m.	223	425			9910	330
6.20 a. m.	228	425				
6.40 a. m.	223	425				
7.00 a. m.	223	425			0170	260
7.20 a. m.	227	450				
7.40 a. m.	228	425				
8.00 a. m.	225	435			5340430	260
8.20 a. m.	225	425				

CALORIMETER LOG.

Recorded by Chas. Rowlands.

Test No. 176.
Date: Feb. 9, 1909.
Time: 8.30 a. m. to 4.30 p. m.

Time.	Cu. ft. of gas.	Cu. cm. of water.	Temperature (deg. F.)				Pressure.		British thermal units.	
			Water.			Gas.	Gas (in. of water).	Barometer (in. of mercury).	As read.	Standardized.
			Inlet.	Outlet.	Difference).					
8.40 a. m.	0.1	285	9.5	19.1	9.6	22.5	....	....	109	....
9.00 a. m.	.1	285	9.5	19.4	9.9	22.5	....	29.34	112	....
9.20 a. m.	.1	290	9.5	19.8	10.3	22.5	....	....	118	....
9.40 a. m.	.1	285	9.5	19.9	10.4	23	....	....	118	....
10.00 a. m.	.1	290	9.8	19.7	9.9	23	....	29.30	114	....
10.20 a. m.	.1	310	9.7	19.8	10.1	23	....	....	124	....
10.40 a. m.	.1	275	9.5	19.3	9.8	23	....	....	107	....
11.00 a. m.	.1	275	9.7	19.9	10.2	23	....	29.25	111	....
11.20 a. m.	.1	295	9.9	19.6	9.7	23.5	....	....	114	....
11.40 a. m.	.1	285	10	19.7	9.7	24	....	....	10	....
12.00 m	.1	275	9.8	19.6	9.8	24	....	29.24	107	....
12.20 p. m.	.1	280	9.6	20	10.4	24	....	....	116	....
12.40 p. m.	.1	280	9.4	20.3	10.9	24	....	....	121	....
1.00 p. m.	.1	300	9.8	19.6	9.8	24	....	29.14	117	....
1.20 p. m.	.1	310	9.8	18.6	8.8	23	....	....	108	....
1.40 p. m.	Gas flame in calorimeter out.									
2.00 p. m.	.1	300	9.6	19.5	9.9	23	....	29.09	118	....
2.20 p. m.	.1	315	9.6	18.7	9.1	23.5	....	....	113	....
2.40 p. m.	.1	260	9.8	20.2	10.4	24	....	....	107	....
3.00 p. m.	.1	270	9.5	20.3	10.8	23	....	29.07	116	....
3.20 p. m.	.1	260	10.0	20.8	10.8	23	....	....	111	....
3.40 p. m.	.1	340	10.3	19.2	8.9	23	....	....	120	....
4.00 p. m.	.1	300	10.3	20.2	9.9	23	....	29.04	118	....
4.20 p. m.	.1	290	10.4	20.9	10.5	23	....	....	121	....

GAS-ANALYSIS LOG.

Recorded by Edward Thomas.

Test No. 176.
Date: Feb. 10, 1909.
Time: 12.30 a. m. to 8.30 a. m.

Time.	12.50 a. m.		2.30 a. m.		7.00 a. m.	
	Per cent by vol.	Calculated B. t. u.	Per cent by vol.	Calculated B. t. u.	Per cent by vol.	Calculated B. t. u.
Carbon dioxide (CO_2)	4.2	....	5.4	....	5.8	....
Oxygen (O_2)	.4	....	.2	....	.9	....
Ethylene (C_2H_4)	.0	....	.0	....	.0	....
Carbon monoxide (CO)	24.8	81.6	23.2	76.3	19.9	65.5
Hydrogen (H_2)	8.9	29.2	11.9	39.0	15.9	52.2
Methane (CH_4)	.8	8.0	.3	3.0	.4	4.0
Nitrogen (N_2)	60.9	....	59.0	....	57.1	....
Total	100.0	118.8	100.0	118.3	100.0	121.7

REPORT OF GAS-PRODUCER OPERATOR.

Test No. 176.
Date: Feb. 10, 1909.
Time: 12.30 a. m. to 8.30 a. m.

TIME.	
12.40 a. m.	Producer in good working shape and everything running smoothly.
2.04 a. m.	Shot fire, and soon after poked fuel bed to fill up holes. There seems to be a tendency for blowholes to form in fuel bed; poked frequently to keep them filled.
3.50 a. m.	Suction at base of producer gradually increasing.
3.55 a. m.	Shot and poked fire; suction reduced to normal.
5.10 a. m.	Producer working well; fuel bed in excellent condition. Removed 9 shovelfuls of lampblack from scrubber dust trap.
6.03 a. m.	Shot and poked fire; gas apparently falling off in heat value; gas consumption increasing.
7.10 a. m.	During the past hour more coal than usual has been charged into the producer, with a resulting increase in the heat value of the gas and a decrease in the gas consumption. Removed 5 shovelfuls of lampblack from dust trap.
8.00 a. m.	Producer in good working condition. Thickness of fuel bed: 2 a. m., 5.8 feet. 4 a. m., 6.0 feet. 6 a. m., 5.9 feet. 8 a. m., 6.0 feet.

E. J. Billings, *Gas-producer operator.*

REPORT OF GAS-ENGINE OPERATOR.

Test No. 176.
Date: Feb. 10, 1909.
Time: 12.30 a. m. to 8.30 a m.

TIME.	
12.30 a. m.	Engine carrying full load easily with gas 6 and air 8.
2.30 a. m.	Opened gas valve to 6¼, leaving air 8. Retarded ignition a little on center cylinder.
3.15 a. m.	Took set of indicator cards; retarded ignition on right cylinder.
3.25 a. m.	Gas valve set back to 6, air 8.
3.35 a. m.	Opened jacket-water inlet valve a small amount and closed from wide open to about half open the cooling-water valve for the exhaust-valve stem.
3.55 a. m.	Gas a little variable; engine fell off in speed slightly; opened gas valve to 6.5 for about 1 minute. Oiled pressure regulator.
4.45 a. m.	Took set of indicator cards.
6.10 a. m.	Set gas valve at 5.9, air 8.
6.45 a. m.	Set gas valve at 5.75, air 8.
6.50 a. m.	Took set of indicator cards; advanced ignition on center cylinder.
6.55 a. m.	Gas 5.5, air 8.
7.05 a. m.	Gas 5.8, air 8. Except for a little variation in the gas, the operation of the engine has been very satisfactory throughout the shift.

D. F. SMITH, *Gas-engine operator.*

OIL AND WASTE REPORT.

Kind of oil: Standard G. E.
Kind of grease ———.
Depth of oil in crank case at beginning of shift, 6 inches.

Test No. 176.
Date: Feb. 10, 1909.
Time: 12.30 a. m. to 8.30 a. m.

TIME.	Oil used on gas engine and accessories:
	0 gallons 6 pints put into oil cups.
	—— gallons 6 pints used during shift.
	0 gallons of oil put in crank case.
	0 pounds of grease put in grease cups.
	0 pounds of waste obtained.

Remarks:

D. F. SMITH, *Gas-engine operator.*

REPORT OF GAS-PRODUCER TEST (1).

Computed by C. A.
Checked by F. E. W. 10, 11, 09.

Test No. 176.
Date: Feb. 8–13, 1909.
Time: ———.

1. Duration of test in hours	104
Average temperatures, degrees F.:	
2. Air entering economizer	74
3. Air and vapor entering producer	366
4. Gas leaving producer	1,242
5. Gas leaving economizer	528
6. Gas leaving wet scrubber	52
7. Gas entering engine	53
Average pressures, inches of water:	
8. Air and vapor entering producer	+ .10
9. Gas leaving producer	− 8.46
10. Gas leaving economizer	− 8.65
11. Gas leaving wet scrubber	−15.50
12. Gas entering dry scrubber	+ 5.21
13. Gas entering engine	+ 2.19
Power to auxiliary motor:	
14. Average horsepower to run exhauster and compressor	3.16
15. Equivalent British thermal units per hour	8,042
Water:	
16. Used in vaporizer, pounds	5,317
17. Used in vaporizer per pound of fuel charged in producer	.32
18. Used in wet scrubber, cubic feet	15,276
19. Used in wet scrubber per rated horsepower of producer per hour	.98
20. Used in wet scrubber per 1,000 cubic feet of gas produced	11.61

REPORT OF GAS-PRODUCER TEST (1)—Continued.

Composition of fuel by weight.	Per cent.	Composition of gas by volume:	Per cent.
21. Moisture	1.37	26. Carbon dioxide (CO_2)	6.22
22. Volatile matter	15.77	27. Oxygen (O_2)	.13
23. Fixed carbon	71.41	28. Ethylene (C_2H_4	.01
24. Ash	11.45	29. Carbon monoxide (CO)	21.05
	100.0	30. Hydrogen (H)	12.01
25. Sulphur	.48	31. Methane (CH_4)	.49
		32. Nitrogen (N_2)	60.09
			100.0

REPORT OF GAS-PRODUCER TEST (2).

Computed by C. A.
Checked by F. E. W.

Test No. 176.
Date: Feb. 8-13, 1909
Time: ——.

Fuel:	
33. Total fuel charged in producer, pounds	16,670
34. Total dry fuel charged in producer, pounds	16,442
35. Per cent of ash in dry fuel	11.61
36. Total ash in fuel, pounds	1,909
37. Total refuse from producer, pounds	2,731
38. Total combustible charged in producer, pounds	14,533
39. Total combustible in refuse, pounds	822
40. Per cent of total combustible consumed	94.34
41. Fuel as fired per hour, pounds	160.3
42. Dry fuel per hour, pounds	158.1
43. Combustible per hour, pounds	139.7
44. Fuel as fired per square foot of fuel-bed area, per hour, pounds	12.37
45. Dry fuel per square foot of fuel-bed area, per hour, pounds	12.20
46. Combustible per square foot of fuel-bed area, per hour, pounds	10.78
Gas (standard at 62° F. and 14.7 pounds pressure):	
47. Total cubic feet produced	1,315,731
48. Cubic feet per hour	12,651
49. Cubic feet per pound of fuel as fired	78.9
50. Cubic feet per pound of dry fuel	80
51. Cubic feet per pound of combustible	90.6
British thermal units:	
52. Per pound of fuel as fired	13,725
53. Per pound of dry fuel	13,916
54. Per pound of combustible	15,743
55. From coal per hour	2,200,118
56. Per cubic foot of standard gas	118.9
57. From gas per hour	1,504,204
Efficiency:	
58. Of conversion of gas	68.37
59. Of producer	68

REPORT OF GAS-ENGINE TEST.

Computed by C. A.
Checked by F. E. W.

Test No. 176.
Date: Feb. 8-13, 1909.
Time: ——.

60. Duration of test in hours	104
61. Revolutions per minute, average	266
62. Explosions per minute, average	133
63. Cubic feet standard gas per hour	12,641
Pressures:	
64. Maximum, first cylinder	310
65. Maximum, second cylinder	295
66. Maximum, third cylinder	314
67. Mean effective, first cylinder	64.51
68. Mean effective, second cylinder	64.61
69. Mean effective, third cylinder	60.33

REPORT OF GAS-ENGINE TEST—Continued.

Power developed:	
70. Indicated horsepower, first cylinder	55.86
71. Indicated horsepower, second cylinder	53.42
72. Indicated horsepower, third cylinder	50.92
73. Total indicated horsepower	[a] 163.40
74. Brake horsepower	139.8
75. Electrical horsepower	120.8
76. Gas horsepower	591

[a] Taken from curve shown in fig. 218 and described on p. 324.

REPORT OF GAS-ENGINE TEST.

Computed by C. A.
Checked by F. E. W.

Test No. 176.
Date: Feb. 8-13, 1909.
Time: ——.

British thermal units per hour:	
77. Equivalent to indicated horsepower developed	407,709
78. Equivalent to brake horsepower developed	355,791
79. Equivalent to electrical horsepower developed	307,436
80. Equivalent to gas horsepower	1,504,204
Thermal efficiency:	
81. Based on indicated horsepower developed and gas horsepower	27.10
82. Based on brake horsepower developed and gas horsepower	23.65
83. Based on electrical horsepower developed and gas horsepower	20.44
Cubic feet of standard gas per hour (62° F. and 14.7 pounds pressure):	
84. Per indicated horsepower developed	78.9
85. Per brake horsepower developed	90.4
86. Per electrical horsepower developed	104.6
Jacket water:	
87. Inlet temperature, °F	38
88. Outlet temperature, °F	129
89. Total cubic feet used	8,484
90. Cubic feet per hour	81.58
91. Cubic feet per indicated horsepower developed per hour	.51
92. Cubic feet per brake horsepower developed per hour	.58

REPORT OF GAS-POWER-PLANT TEST.

Computed by C. A.
Checked by F. E. W.

Test No. 176.
Date: Feb. 8-13, 1909.
Time: ——.

93. Duration of test in hours	104
Horsepower:	
94. Indicated horsepower developed	163.4
95. Indicated horsepower commercially available	159.1
96. Brake horsepower developed	139.8
97. Brake horsepower commercially available	136.1
98. Electrical horsepower developed	120.8
99. Electrical horsepower commercially available	117.6

Fuel consumed per hour:	(a) As fired.	(b) Dry.	(c) Combustible.
100. Per indicated horsepower developed	0.98	0.97	0.85
101. Per indicated horsepower commercially available	1.01	.99	.88
102. Per brake horsepower developed	1.15	1.13	1.00
103. Per brake horsepower commercially available	1.18	1.16	1.03
104. Per electrical horsepower developed	1.33	1.31	1.16
105. Per electrical horsepower commercially available	1.36	1.34	1.19

British thermal units in fuel:	
106. Per indicated horsepower developed per hour	13,725
107. Per brake horsepower developed per hour	15,784
108. Per electrical horsepower developed per hour	18,254

REPORT OF GAS-POWER-PLANT TEST—Continued.

Over all efficiency of plant:	
109. Based on brake horsepower developed	16.12
110. Based on brake horsepower commercially available	15.71
111. Based on electrical horsepower developed	13.94
112. Based on electrical horsepower commercially available	13.63
Water:	
113. Total water used, cubic feet	23,845
114. Water used per hour, cubic feet	229.3
115. Water used per brake horsepower developed per hour, cubic feet	1.64
Miscellaneous:	
116. Pounds of waste used	5
117. Pounds of grease used	0
118. Gallons of oil used	17.375

COMPUTATIONS FOR TEST NO. 176.

Computed by C. A.
Checked by F. E. W. 10, 11, '09. Date: ——

Item 14. $\frac{\text{Watts used}}{746\times\text{item 1}} = \frac{24,540\times10}{746\times104} = 3.16$

15. $2,545\times\text{item 14} = 2,545\times3.16 = 8,042$

17. $\frac{\text{Item 16}}{\text{Item 33}} = \frac{5,317}{16,670} = .32$

19. $\frac{\text{Item 18}}{150\times\text{item 1}} = \frac{15,276}{150\times104} = .98$

20. $\frac{1,000\times\text{item 18}}{\text{Item 47}} = \frac{1,000\times15,276}{1,315,731} = 11.61$

34. $\frac{\text{Item 33}\times[100-\text{item 21}]}{100} = \frac{16,670\times(100-1.37)}{100} = 16,442$

35. $\frac{100\times\text{item 24}}{[100-\text{item 21}]} = \frac{100\times11.45}{100-1.37} = 11.61$

36. $\frac{\text{Item 34}\times\text{item 35}}{100} = \frac{16,442\times11.61}{100} = 1,909$

38. $\text{Item 34}-\text{item 36} = 16,442-1,909 = 14,533$

39. $\text{Item 37}-\text{item 36} = 2,731-1,909 = 822$

40. $\frac{\text{Item 38}-\text{item 39}}{\text{Item 38}}\times100 = \frac{14,533-822}{14,533}\times100 = 94.34$

41. $\frac{\text{Item 33}}{\text{Item 1}} = \frac{16,670}{104} = 160.3$

42. $\frac{\text{Item 34}}{\text{Item 1}} = \frac{16,442}{104} = 158.1$

43. $\frac{\text{Item 38}}{\text{Item 1}} = \frac{14,533}{104} = 139.7$

44. $\frac{\text{Item 41}}{} = \frac{160.3}{12.96} = 12.37$

45. $\frac{\text{Item 42}}{} = \frac{158.1}{12.96} = 12.20$

46. $\frac{\text{Item 43}}{} = \frac{139.7}{12.96} = 10.78$

COMPUTATIONS FOR TEST NO. 176.

Computed by C. A.
Checked by F. E. W.

Date: ——

Item 48. $\frac{\text{Item 47}}{\text{Item 1}} = \frac{1,315,731}{104} = 12,651$

49. $\frac{\text{Item 48}}{\text{Item 41}} = \frac{12,651}{160.3} = 78.9$

50. $\frac{\text{Item 48}}{\text{Item 42}} = \frac{12,651}{158.1} = 80.0$

51. $\frac{\text{Item 48}}{\text{Item 43}} = \frac{12,651}{139.7} = 90.6$

55. $\text{Item 41} \times \text{item 52} = 160.3 \times 13,725 = 2,200,118$

57. $\text{Item 48} \times \text{item 56} = 12,651 \times 118.9 = 1,504,204$

58. $\frac{\text{Item 57}}{\text{Item 55}} \times 100 = \frac{1,504,204}{2,200,118} \times 100 = 68.37$

59. $\frac{\text{Item 57} - \text{item 15}}{\text{Item 55}} \times 100 = \frac{1,504,204 - 8,042}{2,200,118} \times 100 = 68.00$

63. $\text{Item 48} - 10 = 12,651 - 10 = 12,641$

70. $\text{Item 62} \times \text{item 67} \times K_1 = 133 \times 64.51 \times 0.00636 = 55.86$

71. $\text{Item 62} \times \text{item 68} \times K_2 = 133 \times 64.61 \times 0.00635 = 53.42$

72. $\text{Item 62} \times \text{item 69} \times K_3 = 133 \times 60.33 \times 0.006355 = 50.92$

73. $\text{Item 70} + \text{item 71} + \text{item 72} = 55.86 + 53.42 + 50.92 =$ [a] 160.2

74. $\frac{\text{Item 75}}{\text{Eff. of generator} \times \text{eff. of belt}} = \frac{120.8}{.90 \times .96} = 139.8$

75. $\frac{\text{Volts} \times \text{amperes}}{746} = \frac{227 \times 397}{746} = 120.8$

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[a] This item as reported, however, was taken from the curve shown in fig. 218 and described on p. 324.

COMPUTATIONS FOR TEST NO. 176.

Computed by C. A.
Checked by F. E. W.

Date: ——

Item 76. $\frac{\text{Item 57}}{2,545} = \frac{1,504,204}{2,545} = 591$

77. $2,545 \times \text{item 73} = 2,545 \times 163.4 = 415,853$

78. $2,545 \times \text{item 74} = 2,545 \times 139.8 = 355,791$

79. $2,545 \times \text{item 75} = 2,545 \times 120.8 = 307,436$

80. $\text{Item 57} = 1,504,204$

81. $\frac{\text{Item 77}}{\text{Item 80}} = \frac{415,853}{1,504,204} = 27.65$

82. $\frac{\text{Item 78}}{\text{Item 80}} = \frac{355,791}{1,504,204} = 23.65$

83. $\frac{\text{Item 79}}{\text{Item 80}} = \frac{307,436}{1,504,204} = 20.44$

84. $\frac{\text{Item 63}}{\text{Item 73}} = \frac{12,641}{163.4} = 77.4$

85. $\frac{\text{Item 63}}{\text{Item 74}} = \frac{12,641}{139.8} = 90.4$

86. $\frac{\text{Item 63}}{\text{Item 75}} = \frac{12,641}{120.8} = 104.6$

COMPUTATIONS FOR TEST NO. 176—Continued.

Item 90. $\frac{\text{Item 89}}{\text{Item 60}}=\frac{8{,}484}{104}=81.58$

91. $\frac{\text{Item 90}}{\text{Item 73}}=\frac{81.68}{163.4}=.50$

92. $\frac{\text{Item 90}}{\text{Item 74}}=\frac{81.68}{139.8}=.58$

95. $\frac{\text{Item 94}\times\text{item 99}}{\text{Item 98}}=\frac{163.4\times117.6}{120.8}=159.1$

97. $\frac{\text{Item 96}\times\text{item 99}}{\text{Item 98}}=\frac{139.8\times117.6}{120.8}=136.1$

99. Item 75−item 14 $=120.8-3.2=117.6$

COMPUTATIONS FOR TEST NO. 176.

Computed by C. A.
Checked by F. E. W.

Date: ——

	(a)	(b)	(c)
Item 100.	$\frac{\text{Item 41}}{\text{Item 94}}=\frac{160.3}{163.4}=0.98$	$\frac{\text{Item 42}}{\text{Item 94}}=\frac{158.1}{163.4}=0.97$	$\frac{\text{Item 43}}{\text{Item 94}}=\frac{139.7}{163.4}=0.85$
101.	$\frac{\text{Item 41}}{\text{Item 95}}=\frac{160.3}{159.1}=1.01$	$\frac{\text{Item 42}}{\text{Item 95}}=\frac{158.1}{159.1}=.99$	$\frac{\text{Item 43}}{\text{Item 95}}=\frac{139.7}{159.1}=.88$
102.	$\frac{\text{Item 41}}{\text{Item 96}}=\frac{160.3}{139.8}=1.15$	$\frac{\text{Item 42}}{\text{Item 96}}=\frac{158.1}{139.8}=1.13$	$\frac{\text{Item 43}}{\text{Item 96}}=\frac{139.7}{139.8}=1.00$
103.	$\frac{\text{Item 41}}{\text{Item 97}}=\frac{160.3}{136.1}=1.18$	$\frac{\text{Item 42}}{\text{Item 97}}=\frac{158.1}{136.1}=1.16$	$\frac{\text{Item 43}}{\text{Item 97}}=\frac{139.7}{136.1}=1.03$
104.	$\frac{\text{Item 41}}{\text{Item 98}}=\frac{160.3}{120.8}=1.33$	$\frac{\text{Item 42}}{\text{Item 98}}=\frac{158.1}{120.8}=1.31$	$\frac{\text{Item 43}}{\text{Item 98}}=\frac{139.7}{120.8}=1.16$
105.	$\frac{\text{Item 41}}{\text{Item 99}}=\frac{160.3}{117.6}=1.36$	$\frac{\text{Item 42}}{\text{Item 99}}=\frac{158.1}{117.6}=1.34$	$\frac{\text{Item 43}}{\text{Item 99}}=\frac{139.7}{117.6}=1.19$

106. Item 52×item 100a $=13{,}725\times .98=13{,}451$

107. Item 52×item 102a $=13{,}725\times1.15=15{,}784$

108. Item 52×item 104a $=13{,}725\times1.33=18{,}254$

109. $\frac{2{,}545}{\text{Item 107}}\times100=\frac{2{,}545}{15{,}784}\times100=16.12$

110. $\frac{2{,}545}{\text{Item 52}\times\text{item 103a}}\times100=\frac{2{,}545}{13{,}725\times1.18}\times100=15.71$

111. $\frac{2{,}545}{\text{Item 108}}\times100=\frac{2{,}545}{18{,}254}\times100=13.94$

112. $\frac{2{,}545}{\text{Item 52}\times\text{item 105a}}\times100=\frac{2{,}545}{13{,}725\times1.36}\times100=13.63$

113. $\frac{\text{Item 16}}{62.5}+\text{item 18}+\text{item 89}=\frac{5{,}317}{62.5}+15{,}276+8{,}484=23{,}845$

114. $\frac{\text{Item 113}}{\text{Item 93}}=\frac{23{,}845}{104}=229.3$

115. $\frac{\text{Item 114}}{\text{Item 96}}=\frac{229.3}{139.8}=1.64$

REPORT OF GAS-ENGINE INDICATOR CARDS.

Computed by C. A.
Checked by F. E. W.

Test No. 176.
Date: Feb. 10, 1909.
Time: ——

Time.	Cylinder.	Card No.	E. p. m.	Scale of spring.	Pressures.			M. e. p.	Indicated horsepower.	Total indicated horsepower.
					Comp.	Max.	Rel.			
4.45 a. m.	R.	....	133	200	115	320	27	68.00	57.52	....
	C.	....	....	....	125	305	28	66.25	55.95	....
	L.	....	....	....	125	350	25	59.40	50.20	163.7
6.50 a. m.	R.	....	133	200	115	290	26	62.50	52.87	....
	C.	....	....	....	120	235	25	61.25	51.73	....
	L.	....	....	....	120	330	25	62.50	52.83	157.4
10.03 a. m.	R.	....	134	200	110	250	27	63.80	54.37	....
	C.	....	....	....	117	200	30	59.20	50.37	....
	L.	....	....	....	130	330	25	64.40	54.43	159.2
12.03 p. m.	R.	....	133	200	100	255	21	62.20	52.61	....
	C.	....	....	....	100	285	25	62.25	52.58	....
	L.	....	....	....	120	320	23	59.00	49.87	155.0
2.03 p. m.	R.	....	133	200	112	320	30	66.20	56.00	....
	C.	....	....	....	120	310	28	66.00	55.74	....
	L.	....	....	....	115	340	22	61.80	52.23	164.0
4.03 p. m.	R.	....	133	200	115	330	26	67.50	57.27	....
	C.	....	....	....	120	320	27	63.00	53.21	....
	L.	....	....	....	125	360	26	61.00	51.56	162.0
6.05 p. m.	R.	....	133	200	115	290	25	64.00	54.14	....
	C.	....	....	....	120	310	25	65.85	55.62	....
	L.	....	....	....	125	300	22	62.00	52.40	162.2
8.05 p. m.	R.	....	132	200	115	290	25	65.00	54.57	....
	C.	....	....	....	125	300	25	64.90	54.39	....
	L.	....	....	....	115	320	20	57.00	47.82	156.7

CONDITIONS UNDER WHICH THE TESTS WERE CONDUCTED.

The first producer-gas tests made (October, 1904) were begun on a basis of a total of 50 hours for each test. The plant was operated 10 hours a day, and then fires were banked for the night and the run was continued the next morning. This arrangement permitted but one test a week, and as it was desired to test as many coals as possible before the close of the exposition period, a schedule was arranged for conducting two tests per week, each of 30 consecutive hours. Between tests sufficient time was allowed to make the necessary change of fuel and to enable the fuel bed in the producer to be brought to a proper working condition. After the first series of 24 tests had been made, the plant was closed down for several weeks, during which time additional equipment was installed.

Although the results obtained during the early tests were exceedingly gratifying, the operating conditions maintained after resuming the runs in May, 1905, were superior to those that formerly existed. Special attention was directed to the measurement of the coal actually used, and special charts and checking devices were introduced for this purpose.

The determination of the amount of coal actually burned in the producer for any given period is, at best, a factor of more or less uncertainty. To reduce the possible error to a minimum, it was deemed necessary to make the test on each coal as long as practicable. A schedule was therefore adopted in May, 1905, involving two 60-hour tests per week. The first 8 to 12 hours of each run were used for getting the fuel bed into efficient working condition. While complete records were taken during this preparatory period, the official test, as reported, includes only the last 48 or 50 hours of the run, during which time conditions were kept as uniform as possible.

Owing to the lack of reliability in the operation of the gas engine during the exposition period, many of the tests conducted at that time were only of a few hours' duration, but after May, 1905, no difficulty was experienced in starting the engine at 8 a. m. Monday and running it day and night without stop until 8 a. m. Saturday, thus establishing beyond question the reliability of the gas engine when properly handled.

Two different fuels a week were tested, and the change from one gas to the other was made without stopping the engine.

In order to afford additional evidence of the reliability of the gas producer and the gas engine, one test was carried far beyond the usual 60-hour period. The report of this test, which was on coal from a mine at Troy, Ill., lasted 562 consecutive hours, and is of special interest.

An important change was made in the igniter mechanism after the exposition period. The construction of the engine as furnished by the manufacturers allowed no variation of the ignition setting without stopping the engine. With a gas of uniform composition this fixed ignition might suffice, but under the conditions prevailing, with gases from a large variety of fuels, variable ignition was imperative and a special mechanism of simple design, shown in detail in figure 22A, was successfully adapted for this purpose.

Throughout the tests efforts were made to do away with unnecessary appliances. These attempts to simplify the apparatus furnished interesting and valuable information and centered attention on several radical changes in the details of producer-gas plant construction. The elimination of the purifier and the use of brick in place of coke in the scrubber have been described on pages 82 and 84.

In the tests conducted on average bituminous coals no change in the chemical composition of the gas or in the efficiency of the plant was apparent when air at ordinary atmospheric temperature was substituted for preheated air. Accordingly, when the second generator and economizer were installed, the economizer was cut out of service by removing the tubes and closing the air inlet and outlet. The removal of the tubes aided materially in the successful handling of fine, dusty coals, inasmuch as with the regular construction some difficulty had been experienced in using such coals due to the clogging of the tubes by large quantities of coal dust which were continually carried into them by the blast. Figures 22B and 22C give sectional views of the economizer, showing the arrangement of the tubes before their removal.

All coal was delivered to the producer in 150-pound charges, but the interval at which charges were made was varied according to the demands of the producer. The stoking of the fuel bed varied considerably with the character of the fuel. With average grades of coal the stoking interval was approximately 30 minutes.

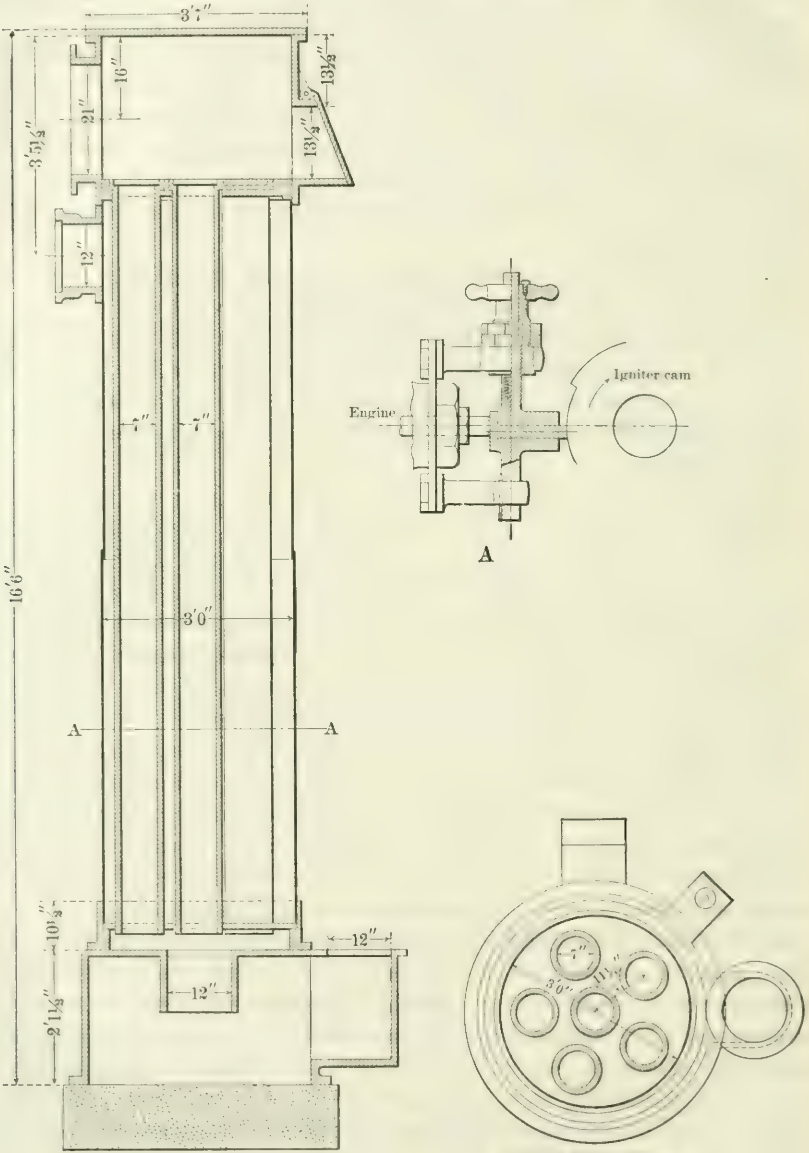


FIGURE 22.—A, Variable-ignition mechanism; B, vertical section of six-tube economizer; C, horizontal section of six-tube economizer.

The ash bed was ground down at very irregular intervals, and usually this operation was accompanied by a decrease in the heat value of the gas. This, however, was not always the case. In general, the thicker the fuel bed the less was the decrease in the heat value of the gas. For this reason if the fuel bed was comparatively thin it was generally built up or made thicker by more frequent fuel charges just before grinding down. The amount the ash bed was ground down at any one time also had a considerable influence on the heat value of the gas, and during the latter part of the testing period at Norfolk the ash bed was ground down much less each time, but more frequently, than during the first part of the period. This method was satisfactory, and in a large measure prevented excessive fluctuations in the heat value of the gas.

The fuels used produced considerable quantities of tar. Figures showing the approximate production of this substance are given in the table on pages 308-313.

Power and light for the fuel-testing plant were supplied by an electric generator and an electric motor driven by the gas engine. The motor load varied considerably, but the load on the engine was kept fairly uniform by means of a water rheostat, which was regulated by the engine operator.

RESULTS OF TESTS.

The following pages contain the tabulated results, graphic logs, and summaries of each test, together with detailed descriptions of the methods of operating during each run.

ST. LOUIS TESTS.

ALABAMA.

Alabama No. 2, test 2.—Alabama No. 2 was a clean, hard coal, which was fed in 1 to 1½ inch lumps. It did not cake excessively and worked well in the producer. The greatest trouble in its use arose from its shrinking away from the walls of the producer, and on this account it was necessary to bar it down against the walls about twice an hour. The lumps did not swell or fuse together. Graphic log is given on page 104.

Alabama No. 4, test 109.—Alabama No. 4 was a clean, bright-looking coal, but a large part of it was very fine when delivered on the producer platform. It gave unsatisfactory results in the producer. At the start the fuel bed was hot, and its temperature seemed to increase as the run continued. Trouble was also experienced from the gas burning in the producer. An attempt to cool the fuel bed by cutting down the air supply resulted in decreasing the heat value of the gas so that the load had to be reduced. The heat value of the gas continued to fall until, after 47 hours run, it was only 68 B. t. u. per cubic foot, and the test was abruptly brought to a close. The computations of the test are based upon the first 24 hours of the run. Graphic log is given on page 105.

Alabama No. 6, test 155.—Alabama No. 6 was a good producer-gas fuel. It worked well in the producer and made a gas of uniform quality having an average heat value of 144 B. t. u. per cubic foot. A standard 50-hour test was made with full load. Graphic log is given on page 106.

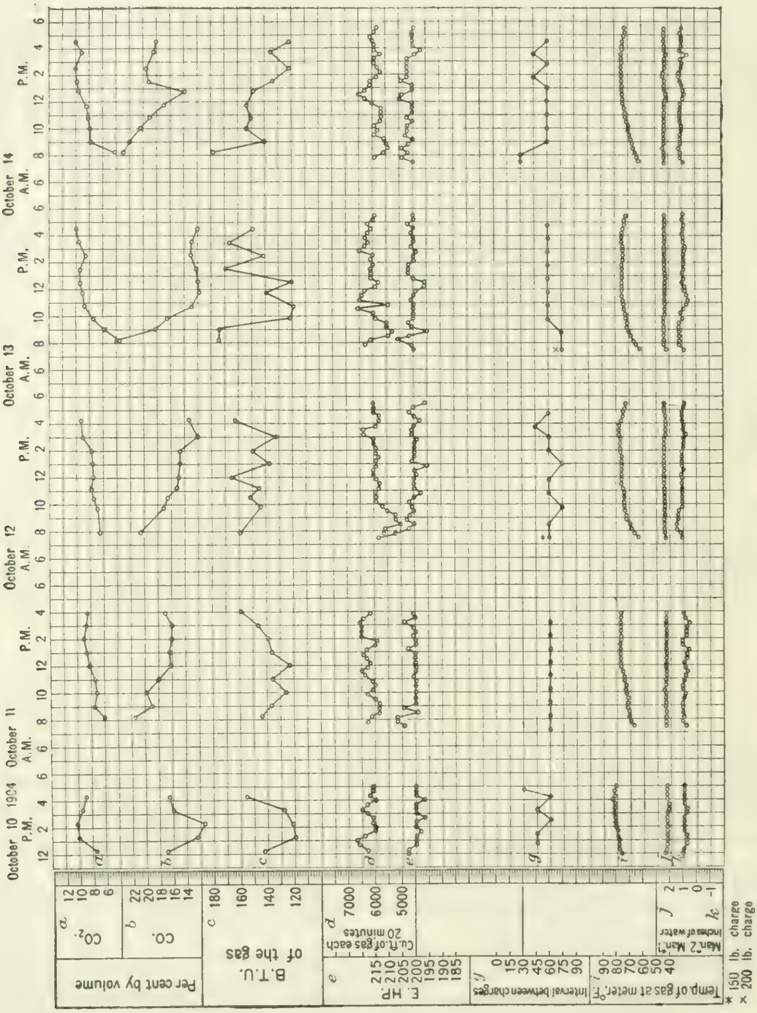


FIGURE 23.—Graphic log sheet, test No. 2, Alabama No. 2 coal.

ARGENTINA.

Argentina (special), test 141.—The sample of fuel brought from Argentina, South America, was of poor quality. Analysis showed it to contain about 43 per cent of ash, only 31 per cent of fixed carbon, and about 18.5 per cent of volatile matter. When delivered on the producer platform it was dusty and contained considerable slate. Before beginning the run the coal was screened. The test was started with a fuel bed of Pennsylvania coal upon which the Argentina coal was charged. For about 4 hours everything ran well and the gas generated was of good quality; then the gas began to decrease in heat value; after 13 hours the engine stopped in spite of every effort to keep it going. It was evident that decrease in heat value began when the Pennsylvania coal in the fuel bed was nearly consumed. The Argentina coal fused so much that it was almost impossible to force a poker through the fuel bed. The blast could get through only around the edge and only this part of the bed produced gas. After the first stop of the engine several attempts were made to get the fuel bed into good working condition and to again start the engine, but without success. It was very difficult to break up and remove the clinker after the producer had cooled

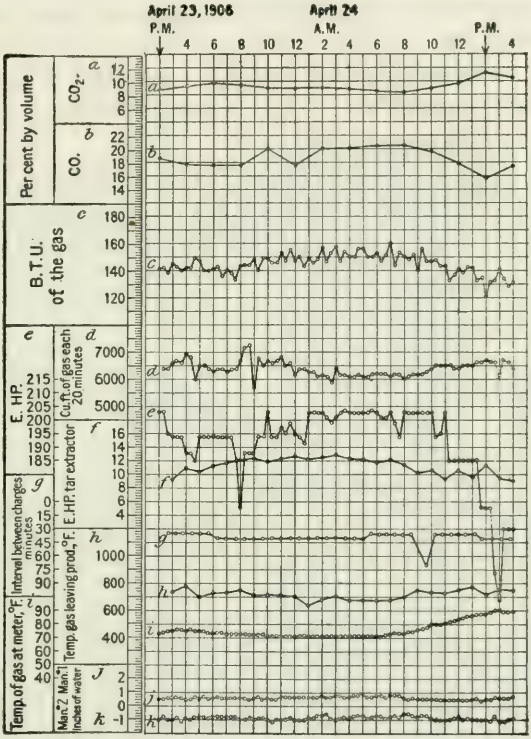


FIGURE 24.—Graphic log sheet, test No. 109, Alabama No. 4 coal.

ARKANSAS.

Arkansas No. 7A, test 96.—This bituminous coal was shipped as lump, but when delivered on the producer platform it was mostly fine coal. In the producer it was handled with difficulty owing to a tendency to fuse, which necessitated an excessive blast pressure. The gas was remarkably uniform in quality and had an average heat value of 126 B. t. u. per cubic foot. A full 50-hour run was made, with about three-fourths full load. Graphic log is given on page 107.

Arkansas No. 8, test 95.—Arkansas No. 8, a semianthracite coal, was delivered to the producer platform as a mixture of slack and lumps up to 4 inches in diameter. During the run something was evidently wrong with the blast in the producer; however, the test lasted 26 hours. The heat value of the gas fluctuated considerably, but averaged 130 B. t. u. per cubic foot for the run. Examination at the close of the test showed that the distributing hood for the blast at the bottom of the producer had become displaced, and in consequence had not properly diffused the blast. Graphic log is given on page 108.

Arkansas No. 10, test 91.—Arkansas No. 10 was a brown lignite, high in moisture. The heat value of the gas produced from this fuel was rather low, averaging 125 B. t. u. per cubic foot for the test, and much of the time it was 100 B. t. u. per cubic foot and even less. It was difficult to keep the fuel bed hot enough. The steam pressure for the blast was unusually high, and was gradually increased until it was 75 pounds; the gas pressure at the top of the producer was then equivalent to 5 inches of water, and the test was stopped. Throughout the run of 18 hours, two-thirds full load was carried. Graphic log is given on page 109.

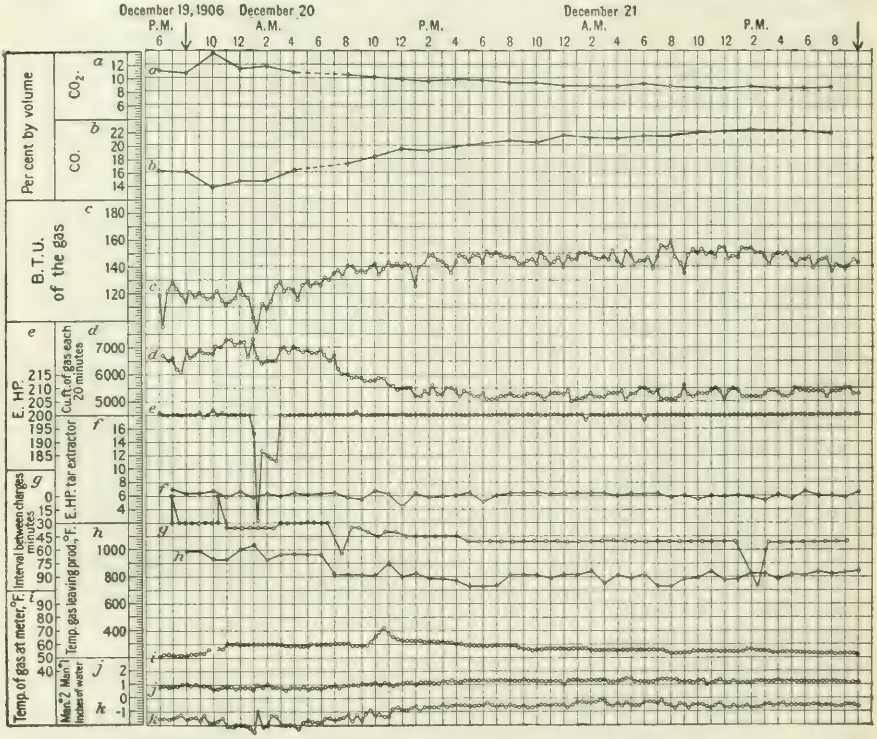


FIGURE 25.—Graphic log sheet, test No. 155, Alabama No. 6 coal.

BRAZIL.

Brazil No. 1, test 44.—Brazil No. 1 was a black, shiny lignite of poor grade. Blow holes and clinker formed in the fuel bed. The gas was poor during the early part of the test and after several hours became so poor that the engine could not carry the load. The fuel bed was put into better condition by careful handling for about 4 hours, and the test started again with about two-thirds full load. Although the gas was not uniform in quality, it had an average heat value of 131 B. t. u. per cubic foot, and a fairly satisfactory 24-hour test was made. Better results undoubtedly can be obtained with this fuel. Graphic log is given on page 110.

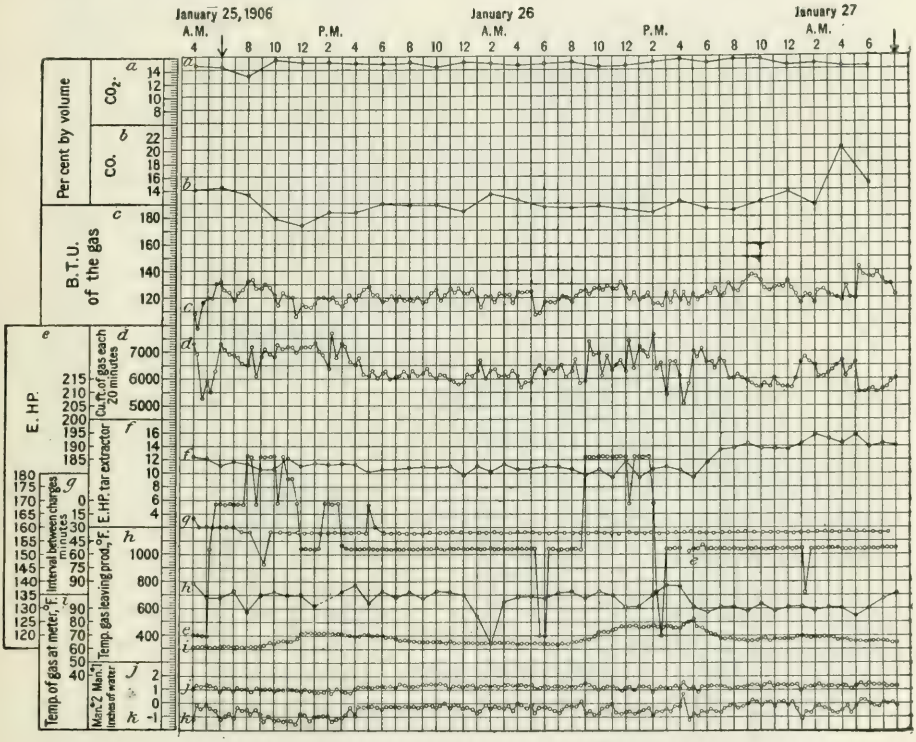


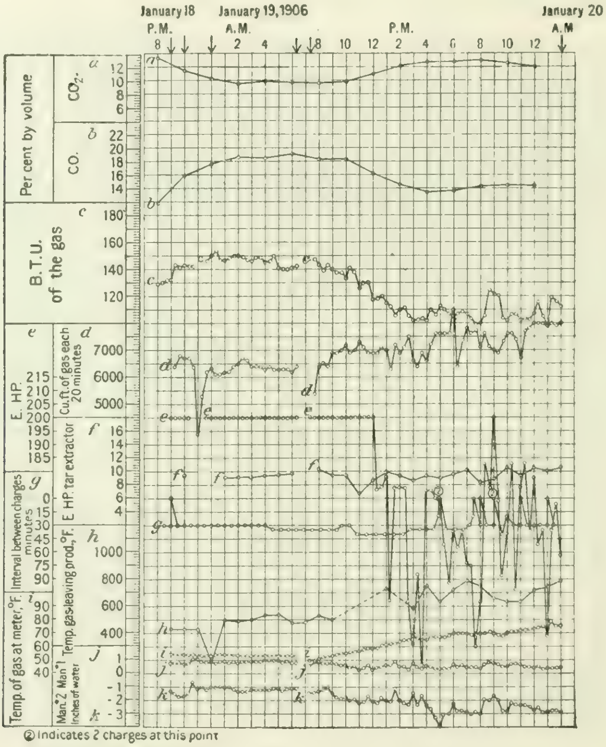
FIGURE 26.—Graphic log sheet, test No. 96, Arkansas No. 7A coal.

CALIFORNIA.

California No. 1, tests 32, 33, and 34.—California No. 1 was a rather poor subbituminous coal. It clinkered in the producer, but not enough to interfere with the proper operation of the plant. The gas was not as uniform in quality as gas from better grades of fuel, but had a heat value which averaged 158 B. t. u. per cubic foot. In determining the fuel equivalent of the steam used by the producer the factor of apparent evaporation was assumed as 4 pounds of water per pound of coal. This figure was derived from results obtained with similar fuels from Colorado, because no steaming test had been made with this coal.

A mixture of California No. 1 and front-end cinders from locomotives, in the proportion of half and half by weight, was fed into the gas producer under normal conditions, and the run continued for several hours, forming test 33. It was found impossible to maintain a supply of gas that would operate the engine under ordinary load. The analyses of the coal and cinders and resulting gas are given in the table on page 272. Graphic log is given on page 112.

A mixture by weight of two-thirds California No. 1 and one-third front-end cinders was used in test 34. This mixture worked much better in the producer than the half-and-half mixture used in test 33, and a fairly good run of 24 hours' duration was made. The heat value of the gas averaged 133 B. t. u. per cubic foot, but varied considerably, necessitating changes in the load on the engine.



② Indicates 2 charges at this point

FIGURE 27.—Graphic log sheet, test No. 95, Arkansas No. 8 coal.

COLORADO.

Colorado No. 1, test 15.—Colorado No. 1 was a subbituminous coal, which clinkered badly in the producer, in spite of frequent poking. The clinkers were not large and could be broken up from the top of the producer. The gas was of a good, uniform quality, and there is no doubt that the fuel can be used to advantage in producers. The coal yielded 60 gallons of yellow tar. Graphic log is given on page 114.

FLORIDA.

Florida No. 1, test 117.—The fuel for test 117 was dark-brown peat, pressed into briquets. The fuel appeared to be dry, but contained 21 per cent of moisture. The content of volatile matter was over 50 per cent. This peat worked remarkably well in the producer. During the first few hours of the test there was a slight tendency to clinker, but later this tendency entirely disappeared and the fuel bed was easily kept in good condition. The gas produced was of uniform quality and had an average heat value of 175 B. t. u. per cubic foot. A load of 241-brake horsepower (normal full load, 235-brake horsepower) was easily carried throughout the entire test of 50 hours. During the first part of the run the tar extractor was not in operation, and the meter was by-passed to avoid any possibility of clogging. The gas was metered, however, during the last 24 hours of the test. Graphic log is given on page 115.

ILLINOIS.

Illinois No. 3, test 6.—The test on this coal was very satisfactory. The gas was of good quality and the coal easily handled. There were no signs of clinkering, and it is certain that this coal could be used continuously without trouble from clinker. It may be considered a good gas-producer coal. Sixty gallons of tar were extracted during the run. Graphic log is given on page 116.

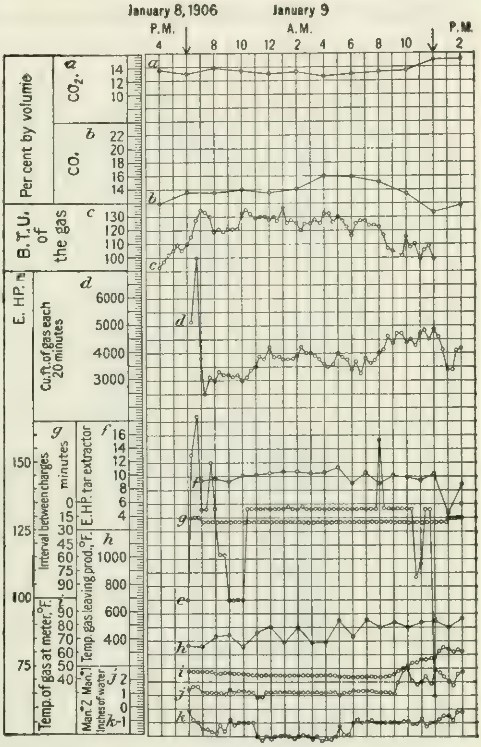


FIGURE 28.—Graphic log sheet, test No. 91, Arkansas No. 10 coal.

Illinois No. 4, test 9.—There was no difficulty during the whole of this test in keeping the producer bed in good condition. The coal yielded 75 gallons of tar and gave a rich gas of uniform quality, which left no trace of tar or sulphur in the engine valves. Graphic log is given on page 117.

Illinois No. 6B, test 35.—Illinois No. 6B was a coal of low calorific power, but it worked well in the producer. The gas was unusually uniform in quality and had an average heat value of 152 B. t. u. per cubic foot. The test was continued for 60 hours with a steady full load. Graphic log is given on page 118.

Illinois No. 7A, test 26.—Three attempts to handle Illinois No. 7A coal in the producer gave poor results. The data given were calculated from the figures obtained in the third trial, a run of 11⅓ hours, on about two-thirds full load. The fineness of the coal and the large percentage of impurities in it caused the failure of this test. Graphic log is given on page 120.

Illinois No. 7B, test 27.—A mixture of nut and pea sizes of Illinois No. 7B coal gave no trouble in the producer, although the coal was high in ash and sulphur. The average heat value of the gas was 139 B. t. u. per cubic foot. A mixture of lime and shavings, tried in the purifier instead of iron oxide, proved of little or no value for removing sulphur from the gas. The test was an excellent 30-hour run, with full load on the engine. Graphic log is given on page 121.

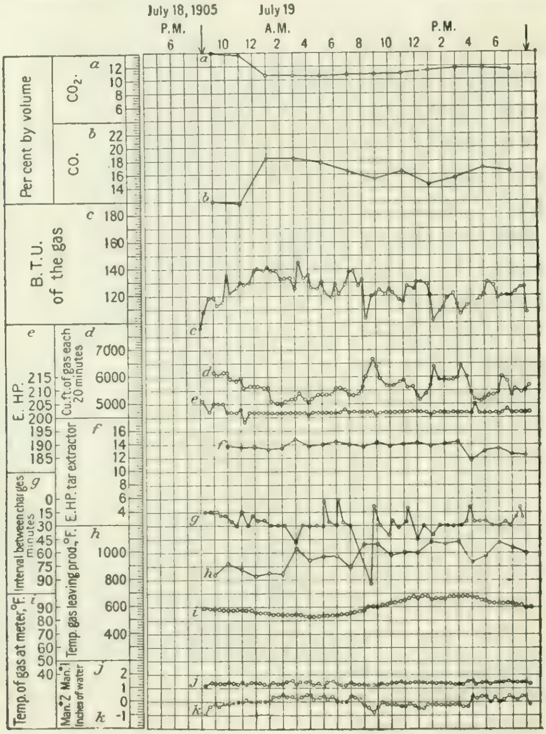


FIGURE 29.—Graphic log sheet, test No. 44, Brazil No. 1 coal.

Illinois No. 7C, test 38.—The test on the poor-quality slack coal designated Illinois No. 7C was not satisfactory. The heat value of the gas varied considerably and averaged 120 B. t. u. per cubic foot. Some difficulty was experienced in handling the fuel bed owing to its tendency to become overheated near the edges. It was also difficult to keep the bed free from holes. The test lasted 33 hours with the engine carrying somewhat less than full load. Graphic log is given on page 122.

Illinois No. 8, test 29.—Illinois No. 8 coal was of fairly good quality. It showed a tendency to clinker, and considerable care was required to prevent the formation of holes in the fuel bed next to the producer walls. The average heat value of the gas was 147 B. t. u. per cubic foot. Preheated air was used for blowing the producer. Full load was carried during the 42-hour test. Graphic log is given on page 123.

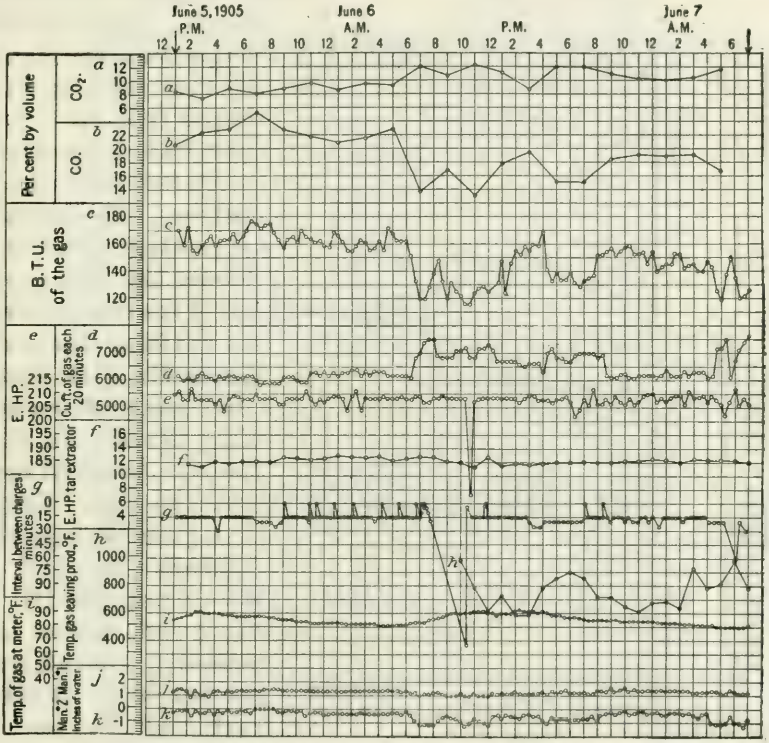


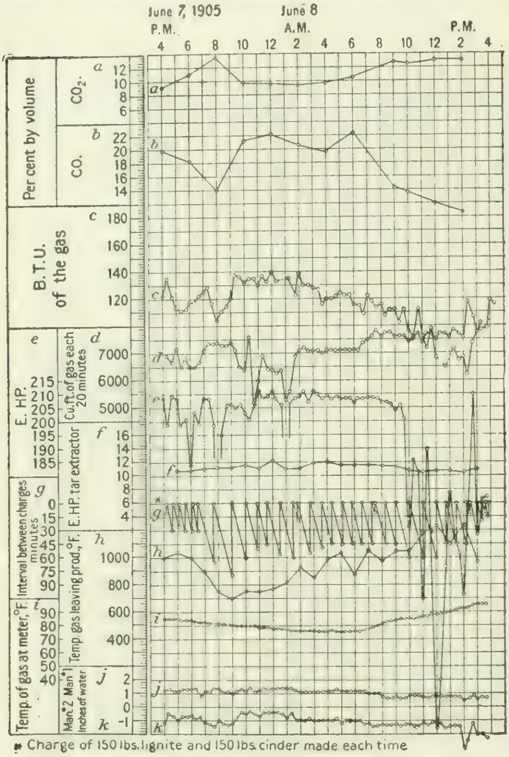
FIGURE 30.—Graphic log sheet, test No. 32, California No. 1 coal.

Illinois No. 9B, test 28.—This coal worked nicely in the producer. During the first half of the test preheated air was used for the blast and during the last half air at atmospheric temperature (averaging 66° F.), but no difference could be noticed in the composition of the gas nor in the working of the fuel bed. The average heat value of the gas was 144 B. t. u. per cubic foot. Full load was carried without interruption during the 60-hour test. Graphic log is given on page 124.

Illinois No. 10, test 31.—Although Illinois No. 10 was in the form of screenings, a good 50-hour run was secured. During this test the gas calorimeter was out of order. The heat value given for the gas

(139 B. t. u. per cubic foot) is the average calculated from the gas analyses. Before beginning this test the purifiers were discarded, investigation having demonstrated the negligible value of the iron oxide or lime purifiers supplied with the plant for removing the sulphur from gas made from coal containing more than 1 per cent of sulphur. Graphic log is given on page 125.

Illinois No. 11A, test 30.—Illinois No. 11A was a very good gas-producer coal in the form of 6-inch lumps, and gave no trouble whatever in the gas generator. Air at atmospheric temperature was used in the blast during the entire test. As the gas calorimeter was out of order, the heat value given for the gas (166 B. t. u. per cubic foot) is the average calculated from the gas analyses. The apparent evaporation taken to determine the coal equivalent of the steam used by the producer was that of Illinois No. 11B, because no steaming test was made with Illinois No. 11A. The test lasted 53 hours, with full load. Graphic log is given on page 126.



* Charge of 150 lbs. lignite and 150 lbs. cinder made each time

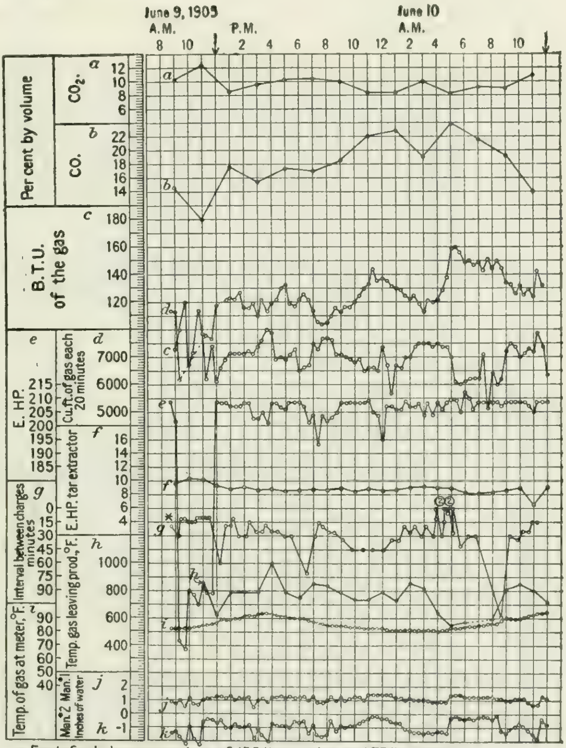
FIGURE 31.—Graphic log sheet, test No. 33, California No. 1 coal.

Illinois No. 11C, test 36.—Illinois No. 11C was No. 5 size washed coal, consisting of small lumps and fine dust. It did not work well in the producer, and the fuel bed got hot around the edges and in the center. The heat value of the gas was low (110 B. t. u. per cubic foot). The test lasted 24 hours, with an average load of 204 brake horsepower. Graphic log is given on page 127.

Illinois No. 11D, tests 42 and 48.—Illinois No. 11D was a washed coal, size No. 3, of good quality. It was easily handled in the producer and required little poking.

In test 42 it made a gas of uniform quality, with an average heat value of 138 B. t. u. per cubic foot. The heat value was determined from the gas analyses as the gas calorimeter was out of order. The test was made in producer No. 7 and lasted 50 hours, with a steady full load on the engine.

In test 48 the second producer, No. 8, was brought into service in order to determine the possibility of duplicating the results secured in producer No. 7. Producer No. 8 was originally 8 feet in internal diameter, but when erected was double lined with fire brick to give it an internal diameter of 7 feet, the same as that of No. 7. The coal consumption of the two producers was practically equal. The average heat value of the gas for test No. 48, as shown by the calorimeter, was 155 B. t. u. per cubic foot. Graphic logs are given on pages 128, 130.



* Each fuel charge consists of 150 lbs. lignite and 75 lbs. cinder
② Indicates 2 charges at this point

FIGURE 32.—Graphic log sheet, test No. 34, California No. 1 coal.

Illinois No. 13, test 41.—The mixture of egg and nut coal called Illinois No. 13 proved to be a good producer fuel. It made a gas of uniform quality, having an average heat value of 138 B. t. u. per cubic foot. The heat value was determined from the gas analyses, as the gas calorimeter was out of order. The test lasted 50 hours with full load. Graphic log is given on page 131.

Illinois No. 14, test 37.—Illinois No. 14, a lump coal of rather poor grade, did not work well in the producer. The gas, however, was of good and uniform quality. The fuel bed showed a tendency to cake, and a great deal of attention was required to keep it in good condition. The duration of the test was 50 hours, with a fairly steady load. Graphic log is given on page 133.

Illinois No. 15, tests 39 and 40.—The lump coal designated as Illinois No. 15 behaved quite well in the producer. Test 39 was a complete failure, on account of the scrubber clogging. The coke was removed from the scrubber and broken brick substituted before beginning test 40. The coal showed a tendency to cake, and the bed had to be poked frequently. The gas was not uniform in quality, but had an average heat value of 143 B. t. u. per cubic foot. No difficulty was experienced in completing the full 50-hour test. Graphic logs are given on pages 135, 136.

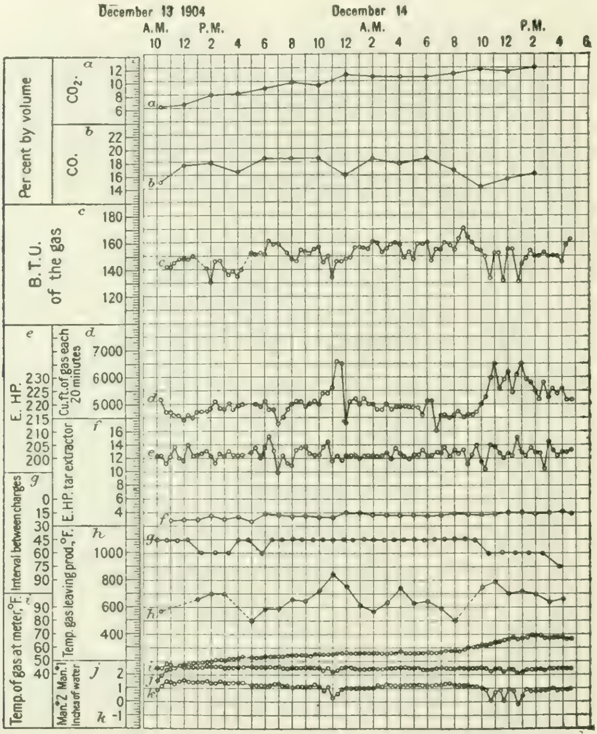


FIGURE 33.—Graphic log sheet, test No. 15, Colorado No. 1 coal.

Illinois No. 16, test 43.—Illinois No. 16, a mixture of lump and egg coal, worked nicely in the producer. The gas was fairly uniform in quality and had an average heat value of 149 B. t. u. per cubic foot. The test lasted 50 hours, with full load. Graphic log is given on page 138.

Illinois No. 18, test 45.—Illinois No. 18, a lump coal, worked well in the producer and made a gas of uniform quality with an average heat value of 148 B. t. u. per cubic foot. The test lasted 50 hours, with full load.

The change from the use of coal passed through a 1½-inch crusher to lump coal was in accord with a decision to test coals as they arrived at the plant, because the majority of operators of producer plants will undoubtedly use coal as bought in the open market. Graphic log is given on page 139.

Illinois No. 19B, test 55.—Illinois No. 19B was a coal of fairly good quality and behaved well in the producer, although the fuel bed required frequent poking. The gas lacked uniformity in quality, but was very rich, having an average heat value of 164 B. t. u. per cubic foot. The test lasted 50 hours, with full load. Graphic log is given on page 140.

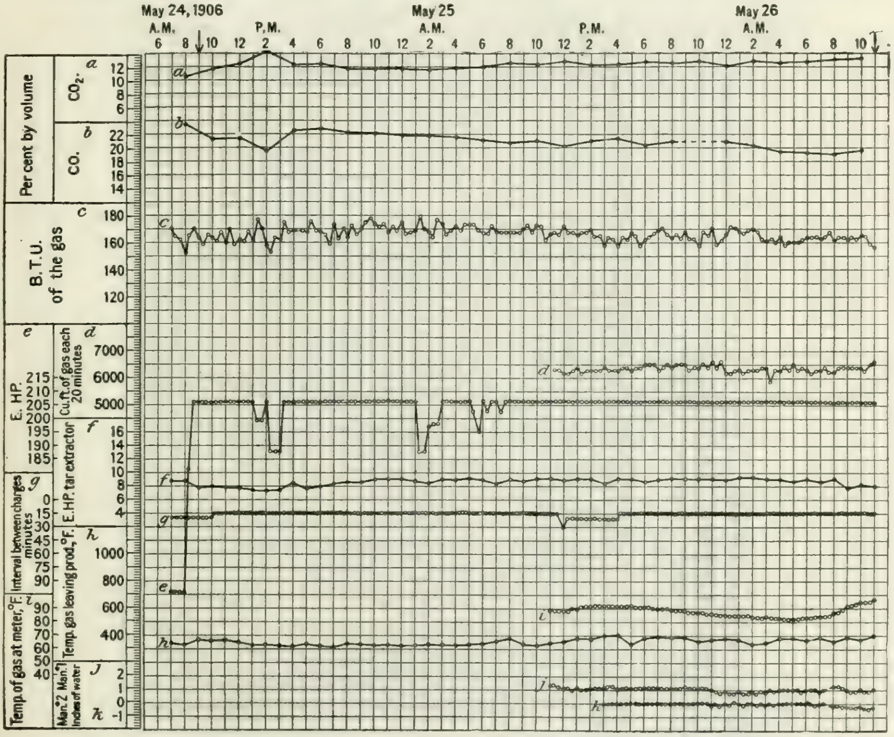


FIGURE 34.—Graphic log sheet, test No. 117, Florida No. 1 coal.

Illinois No. 9C, test 128.—This coal behaved well in the producer and showed no inclination to clinker. The gas was of fairly uniform quality, averaging 138 B. t. u. per cubic foot. Soon after the test started, an accident to the tar-extractor motor put it out of use, and during the 14 hours required for repairs the gas meter was by-passed. The test continued 50 hours, with about three-fourths full load. Graphic log is given in page 141.

Illinois No. 21, test 105.—This was an endurance test, undertaken to demonstrate the possibility of continuous operation of gas engines supplied from producers fed with bituminous coal, and was quite successful, lasting 562 hours without interruption. The coal used gave as an average of six proximate analyses: Moisture, 14.68; volatile matter, 30.98; fixed carbon, 42.93; ash, 11.41; and sulphur (separately determined), 1.33 per cent. The heat value per pound of dry coal was 12,343 B. t. u.

During the test calorimetric determinations of the heat value of the gas were made every 20 minutes, and volumetric analysis every 2 hours. The average heat value of the gas for the entire run was 156.1 B. t. u. per cubic foot, and the average composition was as follows:

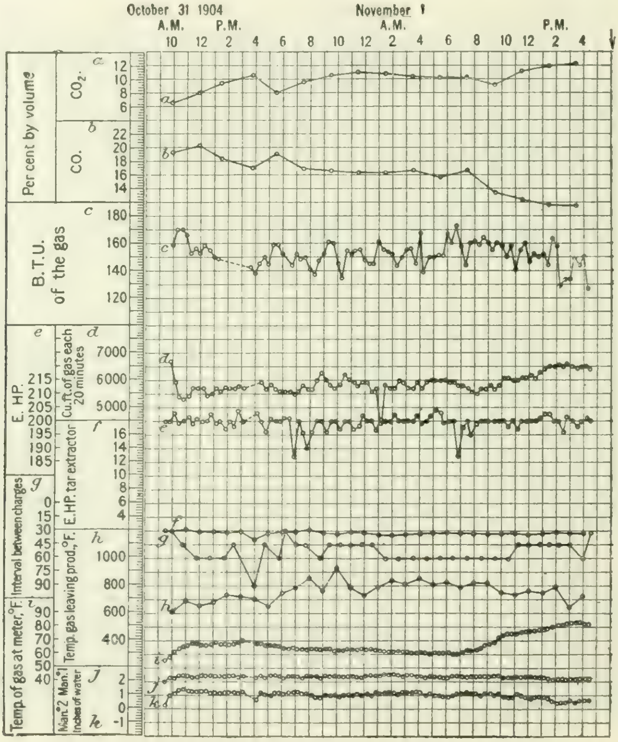


FIGURE 35.—Graphic log sheet, test No. 6, Illinois No. 3 coal.

Hydrogen disulphide (H_2S)	0.0
Carbon dioxide (CO_2)	9.2
Oxygen (O_2)	.0
Ethylene (C_2H_4)	.4
Carbon monoxide (CO)	20.9
Hydrogen (H_2)	15.6
Methane (CH_4)	1.9
Nitrogen (N_2)	52.0
	100.0

Among the items of interest recorded, those relating to the tar are of special importance. The total tar amounted to 14,950 pounds, or about 143 pounds of tar per ton of coal burned in the producer. By heating and stirring the tar, most of the water was extracted, and the figures given are for tar containing not over 10 per cent of water. As the plant was constructed for general test purposes, the passages through which the gas was obliged to flow were far more tortuous than in an ordinary power plant. In going from the dust collector to the scrubber the gas was forced to make three right-angle turns and pass through a water-seal valve, traversing a distance of about 20 feet. This construction, necessary only for testing purposes, was unfortunate, and owing to a deposit of tar in the water-seal valve the test was brought to a close after 24 days. With direct piping better endurance records should be made.

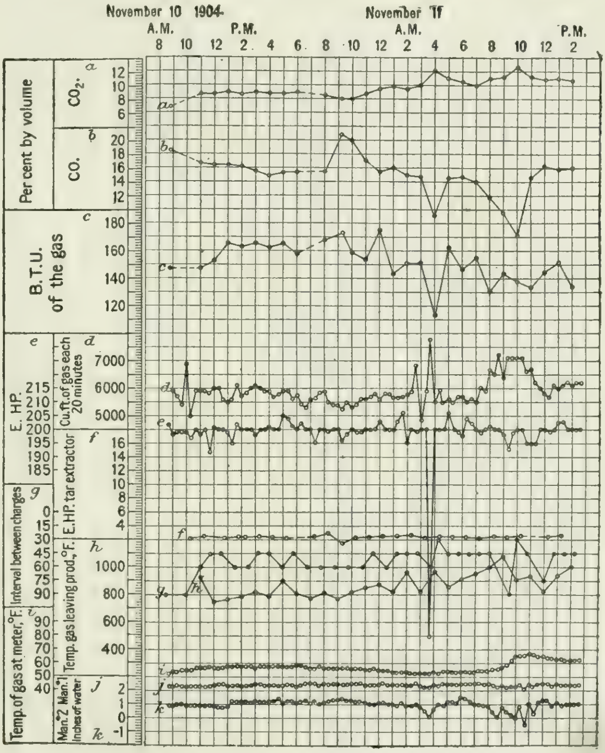


FIGURE 36.—Graphic log sheet, test No. 9, Illinois No. 4 coal.

The producers installed for the tests at St. Louis were not equipped with a water-seal base, which is essential when operating a pressure plant continuously. Without this water-seal base, it is customary to shut down the entire plant in order to remove the ashes, which must be ground down at regular intervals. As such a shutdown would be fatal to an endurance test, a special method of handling the ashes had to be resorted to. The ashes were extracted at about 48-hour intervals by simply reducing the pressure under which the producer was operated and running the plant on the suction basis during the hour required for ash removal. The work was done with ease.

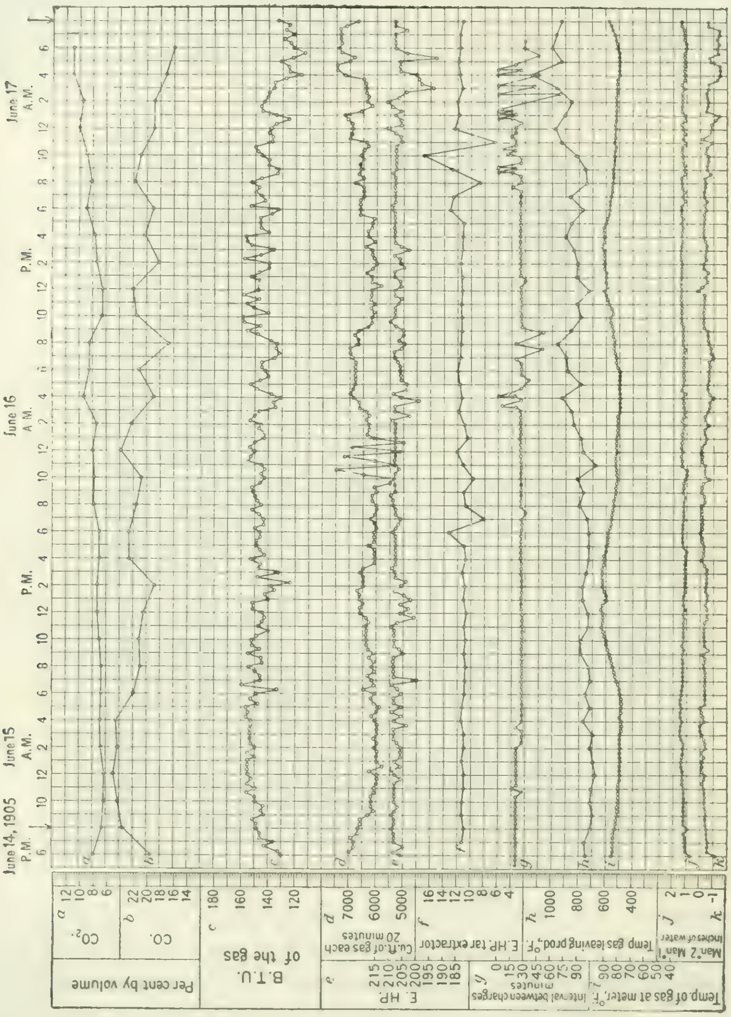
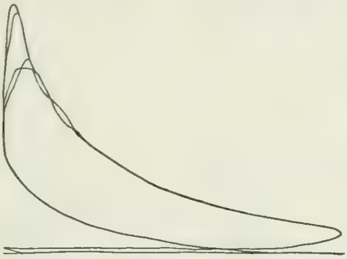


FIGURE 37.—Graphic log sheet, test No. 35, Illinois No. 6B coal.

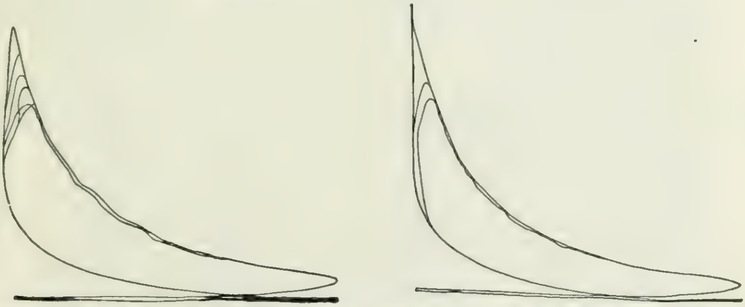
During the entire test the engine showed no signs of heating, clogging with tar, or other trouble. It ran steadily at all times. The same set of igniters was used without difficulty throughout the run. An inspection at the close of the test showed such excellent condition of the cylinders, igniters, and all working parts that the engine was not cleaned nor its mechanism changed in any way before beginning the next test. An inspection of the producer plant showed that everything was in good condition with the single exception of the clogged water-seal valve.

During the test the average load was 225.5 brake horsepower and the coal consumption was 1.40 pounds (dry) per brake-horsepower hour. Especial attention is called to the fact that during this run, as well as during all subsequent tests at this plant, no attempt was made to remove the sulphur from the gas supplied to the engine. Graphic logs are given on pages 142, 143, 144, 145, 146, 147, 148.

Illinois No. 22A, test 102.—Illinois No. 22A worked well in the producer during the entire run. The gas was unusually uniform in quality and had an average heat value of 160 B. t. u. per cubic foot. Full load was carried for 47 hours, after which time an accumulation of soot in the economizer interfered with the flow of gas and made it necessary to reduce the load to about three-fourths full load. Though the run lasted 50 hours, the data used are for the time during which full load was maintained. Graphic log is given on page 148.



Center cylinder. M. E. P., 66; Max., 272; Rel., 30; I. H. P., 104.0.



Right cylinder. M. E. P., 64; Max., 272; Rel., 28; I. H. P., 100.8.

Left cylinder. M. E. P., 60; Max., 308; Rel., 22; I. H. P., 94.6.

FIGURE 38.—Indicator cards, test No. 35, Illinois No. 6B coal. Scale of spring, 80; revolutions per minute, 200.

Illinois No. 23A, test 98.—Illinois No. 23A, a lump coal, was hard to handle in the producer and had a tendency to clinker. The heat value of the gas was uniform and averaged 148 B. t. u. per cubic foot. The tar was unusually black and heavy and gave trouble at the tar extractor if cooled too much. The duration of the test was 50 hours, with full load. Graphic log is given on page 149.

Illinois No. 23B, test 100.—Illinois No. 23B, a washed coal, when delivered on the producer platform was very fine. Except for a slight tendency of the fuel bed to heat around the edges, the coal worked well in the producer. Little clinker formed. The heat value of the gas was fairly uniform and averaged 145 B. t. u. per cubic foot. The gas passage in the economizer became partly clogged, and it was necessary to reduce the load to about four-fifths full load. A full 50-hour test was made. Graphic log is given on page 149.

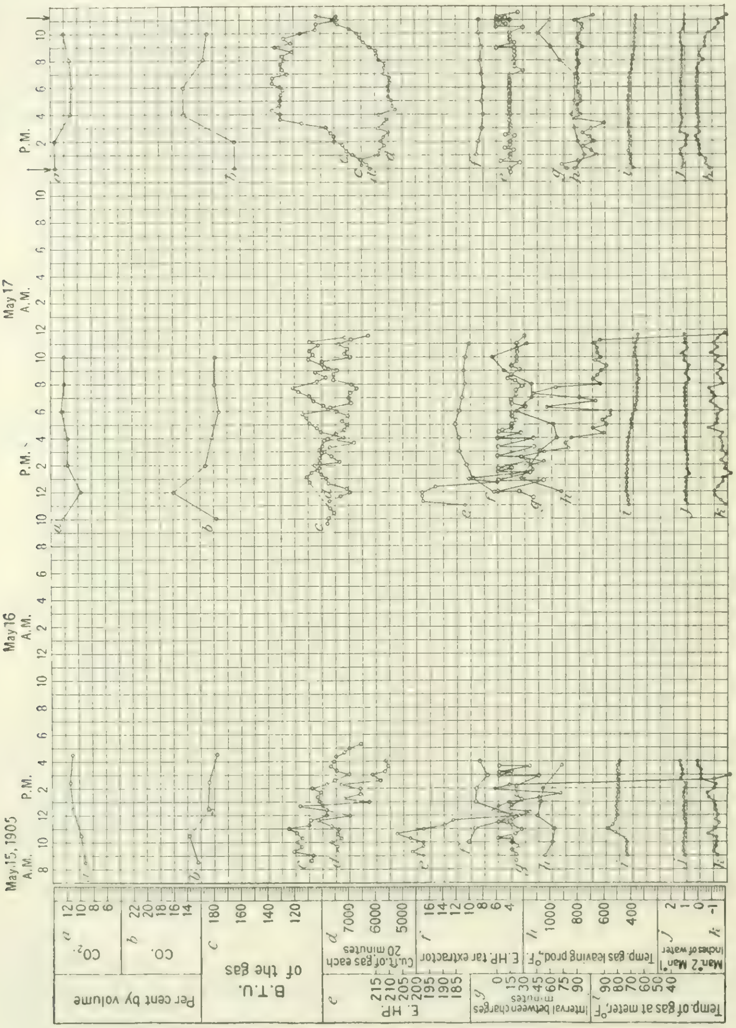


FIGURE 39.—Graphic log sheet, test No. 26, Illinois No. 7A coal.

Illinois No. 24B, test 103.—Illinois No. 24B, a clean, bright-looking coal, worked well in the producer and gave no indications of clinkering. During the run 300 pounds of coal were charged per hour. The heat value of the gas was uniform and averaged 161 B. t. u. per cubic foot. Full load was easily carried throughout the 50-hour test. Graphic log is given on page 150.

Illinois No. 25, test 104.—Illinois No. 25, a clean, bright coal, worked very satisfactorily in the producer. It was easily handled, and throughout the run little fire was visible on top of the fuel bed. The heat value of the gas was remarkably uniform and averaged 168 B. t. u. per cubic foot. The duration of the test was 50 hours, with a steady full load. Graphic log is given on page 150.

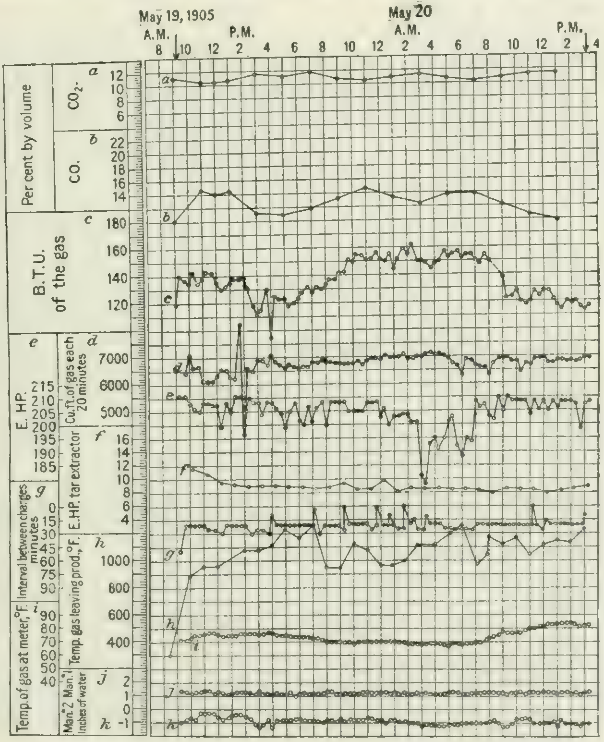


FIGURE 40.—Graphic log sheet, test No. 27, Illinois No. 7B coal.

Illinois No. 26, test 126.—Illinois No. 26, consisting almost entirely of slack, worked well in the producer, and during the greater part of the test yielded a gas of good and fairly uniform quality. Toward the end of the test, however, the ash bed became too thick, causing an unequal distribution of the blast through the fuel bed and a consequent lowering of the heat value of the gas. On the 50-hour run the average heat value of the gas was 147 B. t. u. per cubic foot, and about 85 per cent of full load was carried. Graphic log is given on page 121.

Illinois No. 27, test 127.—Illinois No. 27 was delivered on the producer platform after lying exposed to the weather for 5 months, in which time it had become quite thoroughly slacked. A fair test, however, was made. Increase of the blast pressure had a tendency to form channels in the fuel bed. The gas, which contained a high percentage of carbon dioxide (12.4 per cent), was of poor and variable quality. The average heat value was 123 B. t. u. per cubic foot. The test lasted 50 hours, with little over one-half full load. Graphic log is given on page 151.

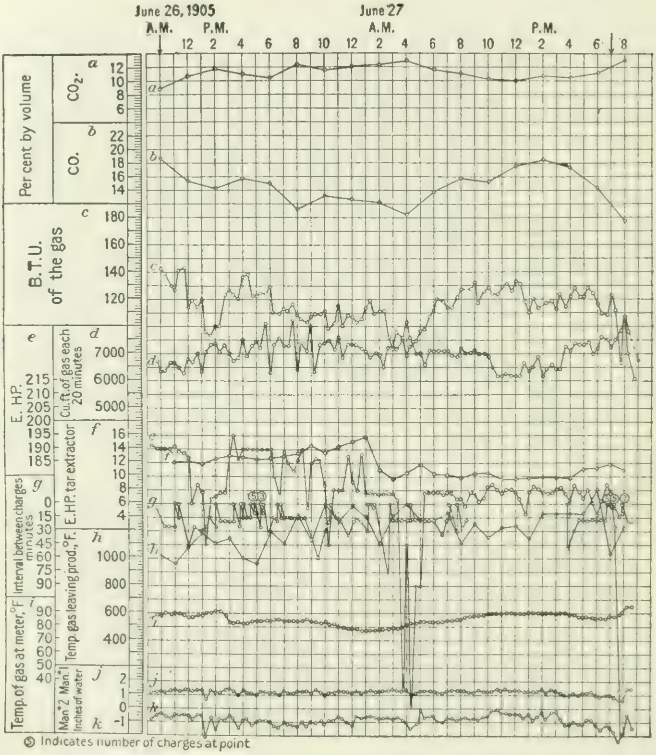
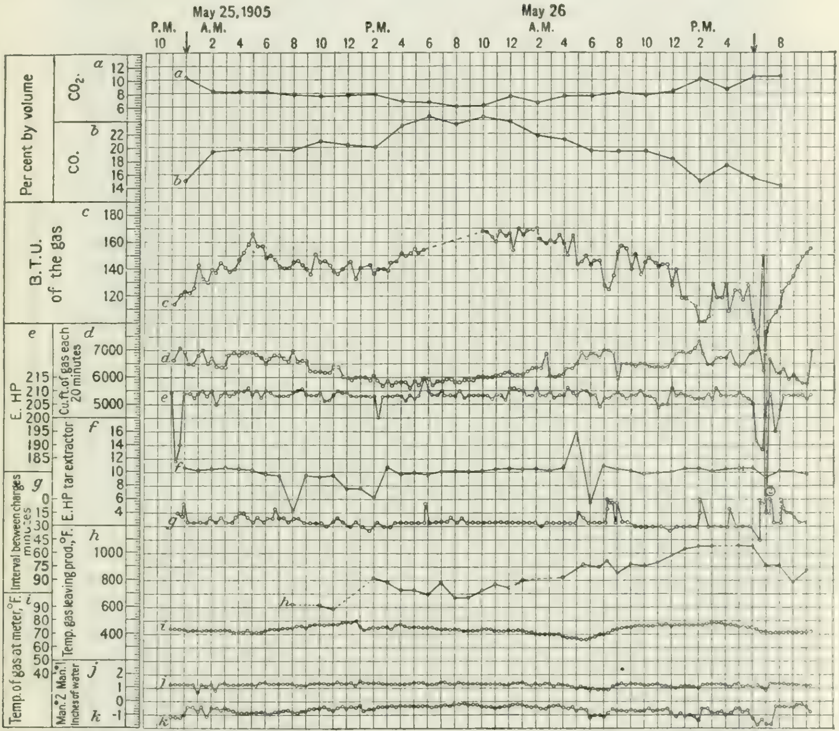


FIGURE 41.—Graphic log sheet, test No. 38, Illinois No. 7C coal.

Illinois No. 29B, test 139.—This Illinois average run-of-mine coal worked well in the producer. The gas was of fairly uniform quality during the greater part of the run. At the beginning of the test the ash bed was rather high, and probably owing to this condition the heat value of the gas later began to decrease. The ash bed was ground down, and after considerable poking of the fuel bed the heat value of the gas rose and was on the increase when the test ended. A standard 50-hour run was made, with approximately full load. The gas meter was by-passed during the entire test. Graphic log is given on page 152.

Illinois No. 30, test 157.—Illinois No. 30, a washed coal, worked well in the producer and gave no trouble from clinker. Throughout the test, however, the ash bed was rather high, and at times the fuel bed was a little thin, causing a fluctuation in the heat value of the gas, which averaged 154 B. t. u. per cubic foot. A large amount of thick, black tar was obtained from this coal. A steady full load was easily carried during a 50-hour test. There was no steaming test on this coal, and the apparent evaporation was calculated.[a] Graphic log is given on page 152.



② Indicates 2 charges (150 lbs each) at this point

FIGURE 42.—Graphic log sheet, test No. 29, Illinois No. 8 coal.

INDIANA.

Indiana No. 1, test 14.—The gas from this coal was of uniformly good quality. No trouble was experienced in working the bed, and the coal may be considered an excellent producer fuel. It yielded about 70 gallons of black tar. Graphic log is given on page 153.

Indiana No. 2, tests 13A and 13B.—The gas produced was somewhat difficult to clean and contained a high percentage of sulphur. During the early part of the test the gas was of low heat value, but improved after the depth of the fuel bed was increased. Good results may be obtained from this coal if it is properly fired in the producer. Sixty gallons of tar were extracted. Graphic log is given on page 153.

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[a] The formula used for this calculation is $x=\frac{0.65\ H}{1.20\times 966}$, in which x is the apparent evaporation in pounds for 1 pound of fuel, H is the heat value of a pound of fuel expressed in British thermal units, 1.20 is the factor of evaporation, and 0.65 is the assumed average efficiency of the steam boiler as determined from a large number of tests.

Indiana No. 3, test 53.—Indiana No. 3 was a mixed nut and slack coal which had been washed. It caked considerably in the producer, but with frequent poking the fuel bed was kept in good condition. The heat value of the gas was uniform and averaged 137 B. t. u. per cubic foot. The test lasted 50 hours, with approximately full load. Graphic log is given on page 154.

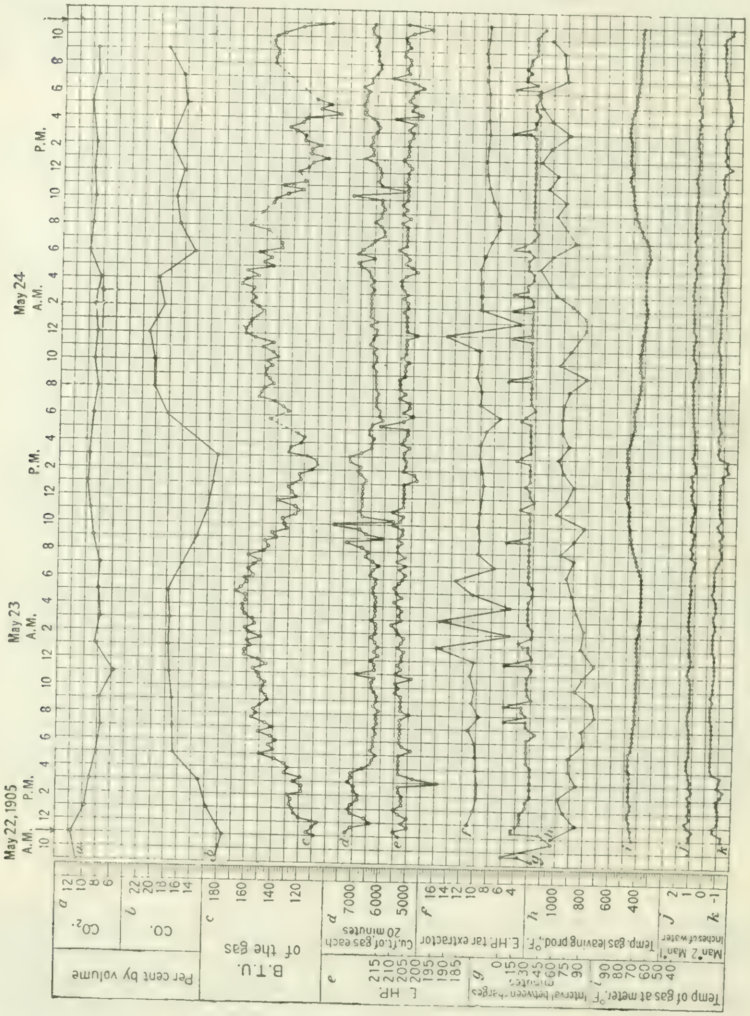


FIGURE 43.—Graphic log sheet, test No. 28, Illinois No. 9B coal.

Indiana No. 5, tests 46 and 47.—The run-of-mine coal designated Indiana No. 5 did not work well in the producer during test 46, probably owing to the thinness of the fuel bed. The gas was of poor and variable quality at the beginning of the test, but at the end of the run had an average heat value of 137 B. t. u. per cubic foot. On account of the producer clogging, the test came to an abrupt close after 30 hours, during which time the load on the engine, although not steady, averaged the full rating.

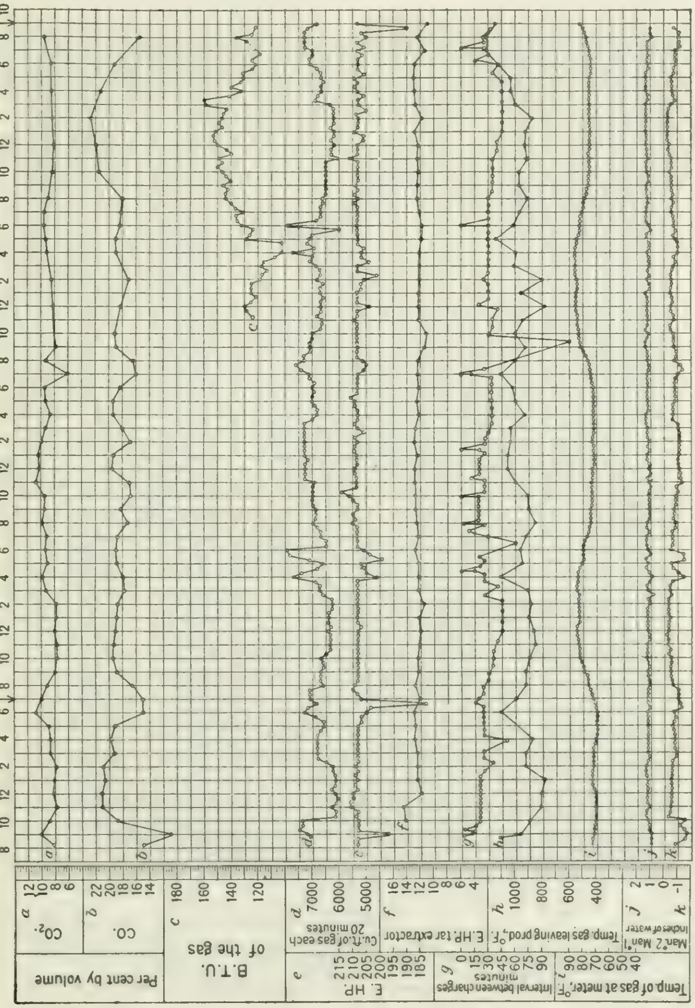


FIGURE 44.—Graphic log sheet, test No. 31, Illinois No. 10 coal.

Test 47 was made as a duplicate test on account of the partial failure of the preceding one. The fuel for this test was easily handled in the producer and made a gas of uniform quality and with an average heat value of 145 B. t. u. per cubic foot. No difficulty was experienced in completing a test of standard length (50 hours) with full load.

The accuracy of the figures under "Gas per hour," 16,970 cubic feet, is doubtful. The recorded reading seems low. The gas meter was immediately afterwards found to be out of order, and may not have given correct readings during part of the run. Graphic logs are given on pages 154 and 155.

Indiana No. 6, test 49.—The run-of-mine coal designated Indiana No. 6 worked well in the producer, making gas of uniform quality and with an average heat value of 151 B. t. u. per cubic foot. The test lasted 50 hours, with full load. The gas meter was out of order during the run, and the thermometer and manometer readings were necessarily omitted. During the latter part of the test the gas calorimeter began to leak, and gas analyses were thereafter made every hour. Graphic log is given on page 155.

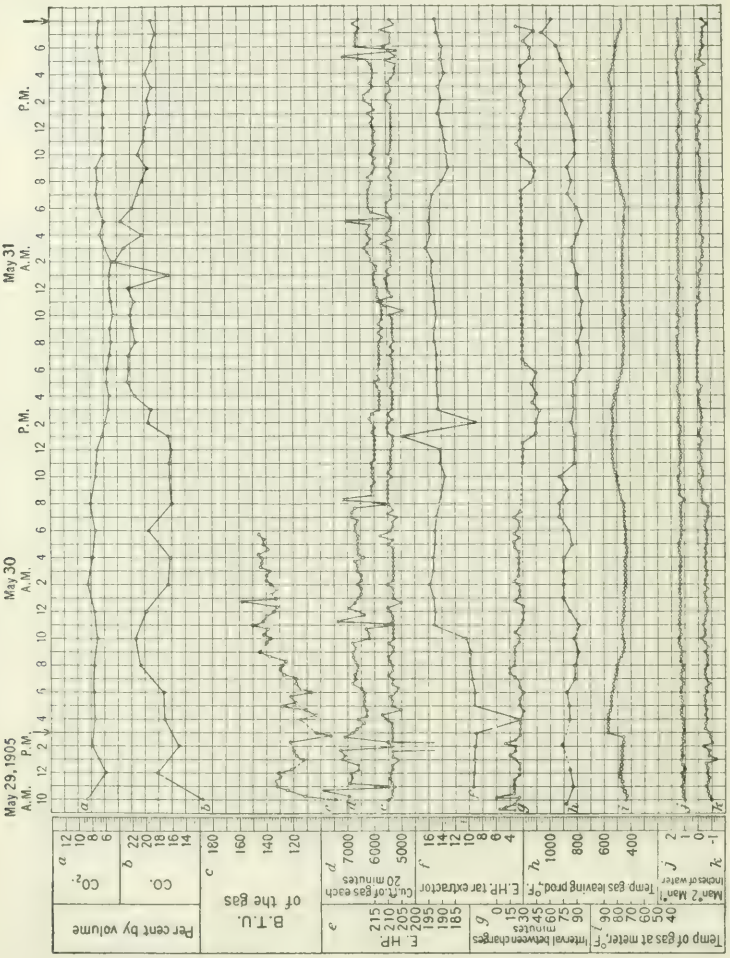
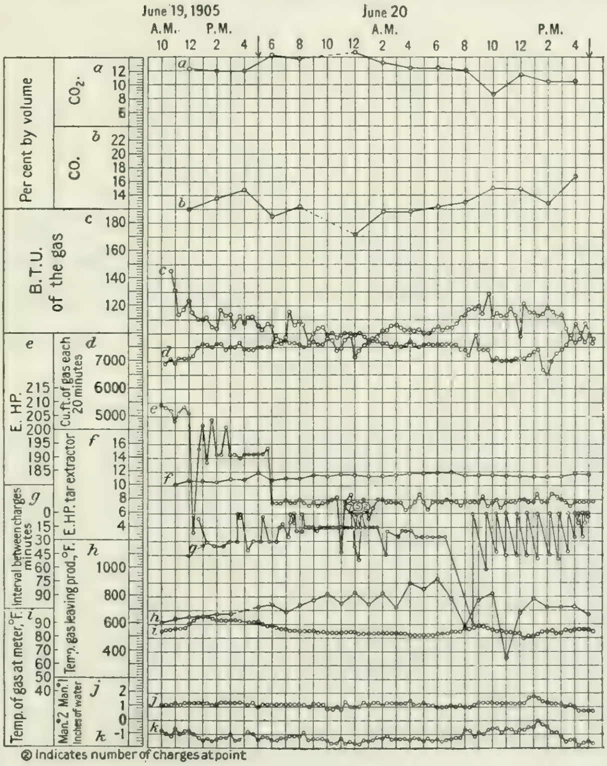


FIGURE 45.—Graphic log sheet, test No. 30, Illinois No. 11A coal.

Indiana No. 7A, test 51.—The mixed sample of lump, egg, and nut coal, designated Indiana No. 7A, proved to be a good producer fuel, making a rich gas of uniform quality without much labor expended on the fuel bed. The average heat value of the gas was 158.5 B. t. u. per cubic foot. The gas meter was temporarily out of order toward the close of the test, and on this account the portion of the run used in the computations is reduced to 45 hours, during which period the engine carried full load. Graphic log is given on page 156.

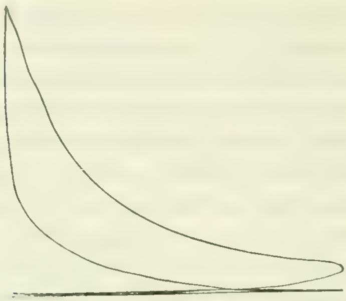
Indiana No. 8, test 57.—The sample of nut coal known as Indiana No. 8 was a good gas-producer fuel, making a gas with a heat value of 151.5 B. t. u. per cubic foot and of uniform quality. The duration of the test was 50 hours, with full load. Graphic log is given on page 156.



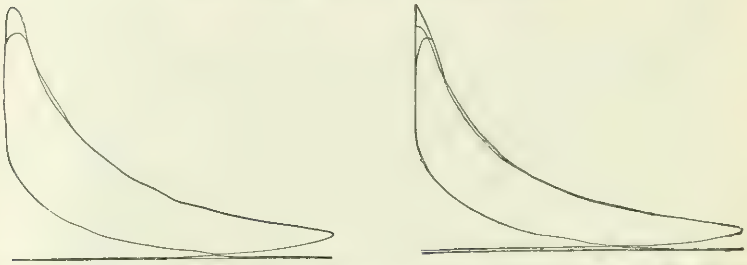
② Indicates number of charges at point

FIGURE 46.—Graphic log sheet, test No. 36, Illinois No. 11C coal.

Indiana No. 9A, test 52.—Some difficulty was experienced during the early portion of the run on Indiana No. 9A, a lump coal. It became apparent early in the test that the fuel bed was too thin. After the proper depth was secured no further trouble was encountered. The heat value of the gas was fairly uniform and averaged 152 B. t. u. per cubic foot. Deducting the extra time required in



Center cylinder. M. E. P., 70; Max., 320; Rel., 34;
I. H. P., 108.7.



Right cylinder. M. E. P., 72; Max., 278; Rel., 34,
I. H. P., 111.7.

Left cylinder. M. E. P., 60; Max., 268; Rel., 30;
I. H. P., 93.2.

FIGURE 47.—Indicator cards, test No. 36, Illinois No. 11C coal. Scale of spring, 80; revolutions per minute, 197.

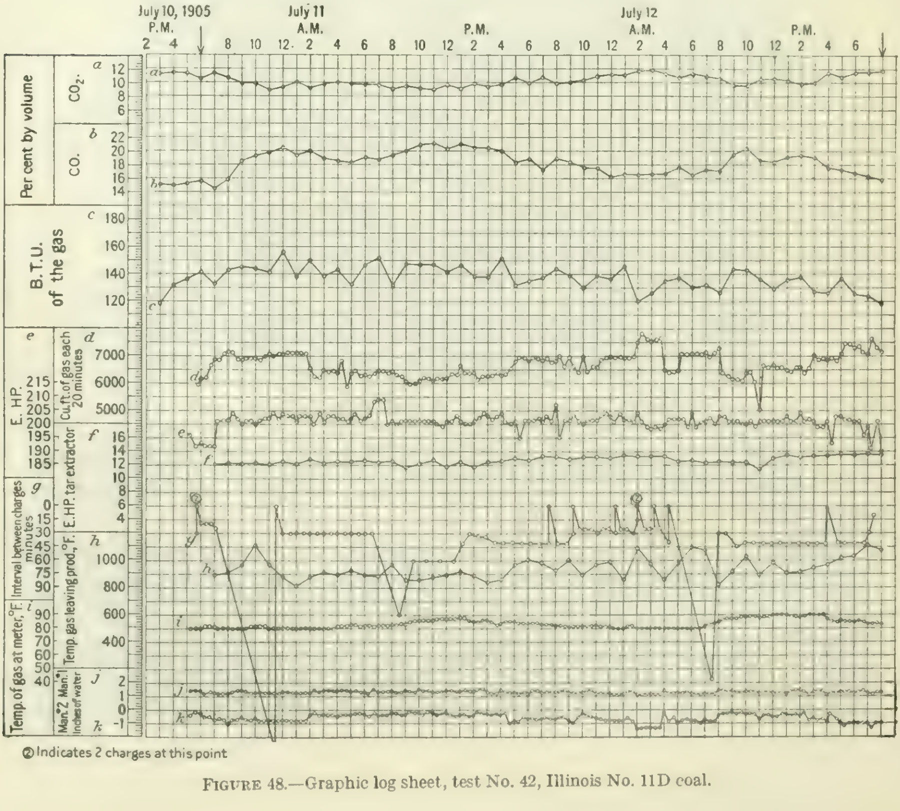
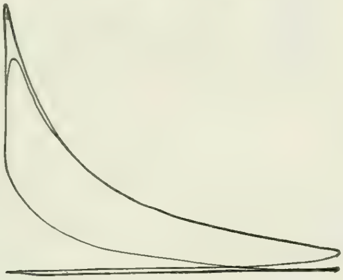


FIGURE 48.—Graphic log sheet, test No. 42, Illinois No. 11D coal.

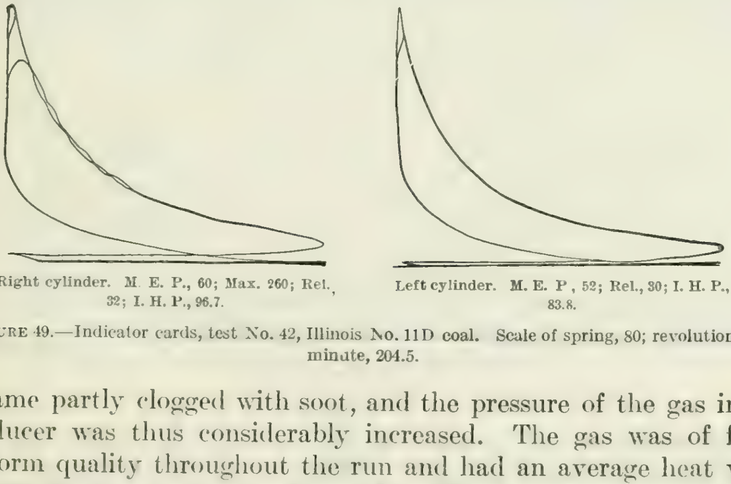
getting the fuel bed into proper condition, a very satisfactory 45-hour test was completed. Graphic log is given on page 157.

Indiana No. 11, test 81.—Indiana No. 11, a lump coal, was a fairly good producer-gas fuel, not requiring close attention. The heat value of the gas was reasonably uniform and averaged 147 B. t. u. per cubic foot. The test lasted 40 hours, with steady full load. Graphic log is given on page 157.

Indiana No. 12, test 99.—Indiana No. 12 was a run-of-mine coal delivered on the producer platform, crushed to egg size. It worked well throughout the test, but had a slight tendency to cake at the top of the fuel bed. At the end of about 30 hours the economizer became partly clogged with soot, and the pressure of the gas in the producer was thus considerably increased. The gas was of fairly uniform quality throughout the run and had an average heat value of 149 B. t. u. per cubic foot. No difficulty was experienced in completing a full 50-hour test under approximately full load. Graphic log is given on page 158.



Center cylinder. M. E. P., 60, Max., 280, Rel., 32, I. H P. 96.7



Right cylinder. M. E. P., 60; Max. 260; Rel., 32; I. H. P., 96.7.

Left cylinder. M. E. P, 52; Rel., 30; I. H. P., 83.8.

FIGURE 49.—Indicator cards, test No. 42, Illinois No. 11D coal. Scale of spring, 80; revolutions per minute, 204.5.

Indiana No. 13, test 132.—Indiana No. 13 was a dirty-appearing coal and contained much slack. During the first part of the test the fuel bed was in fairly good condition and the gas was moderately uniform in quality, with a heat value of about 140 B. t. u. per cubic foot. Toward the end of the test, however, the fuel bed became very

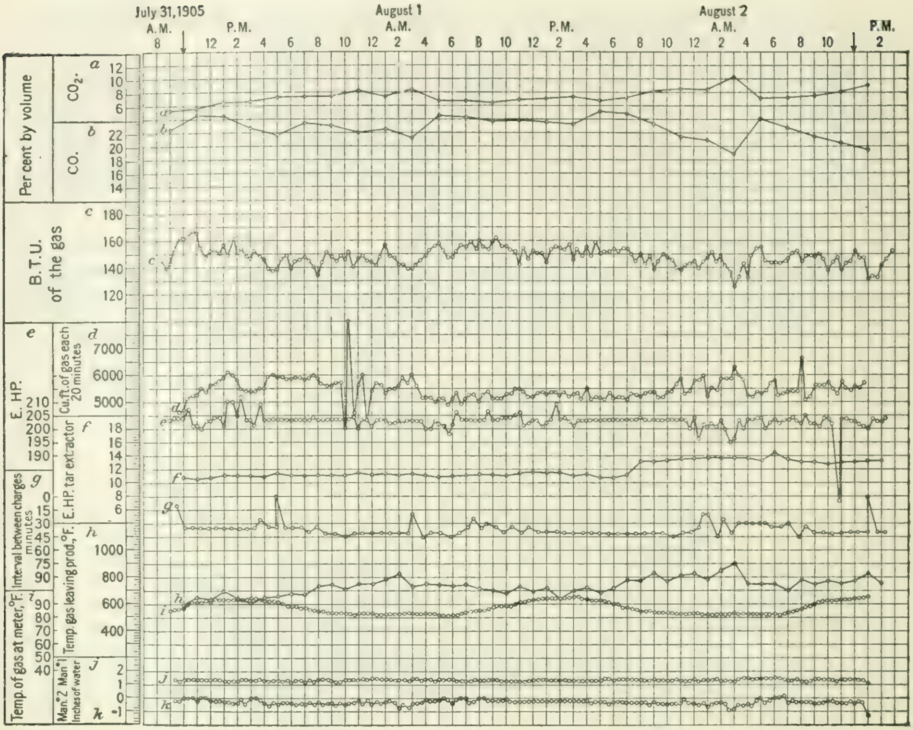
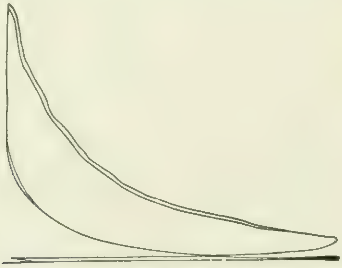
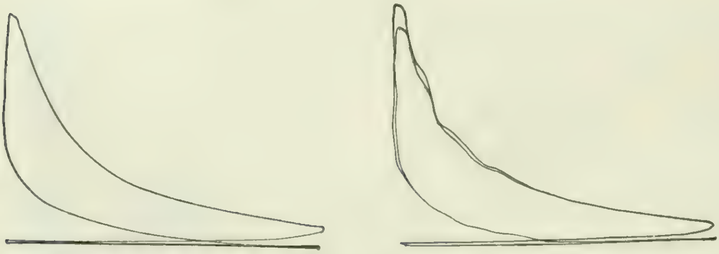


FIGURE 50.—Graphic log sheet, test No. 48, Illinois No. 11D coal.



Center cylinder. M. E. P., 66; Max., 294; Rel., 28; I. H. P., 105.4.



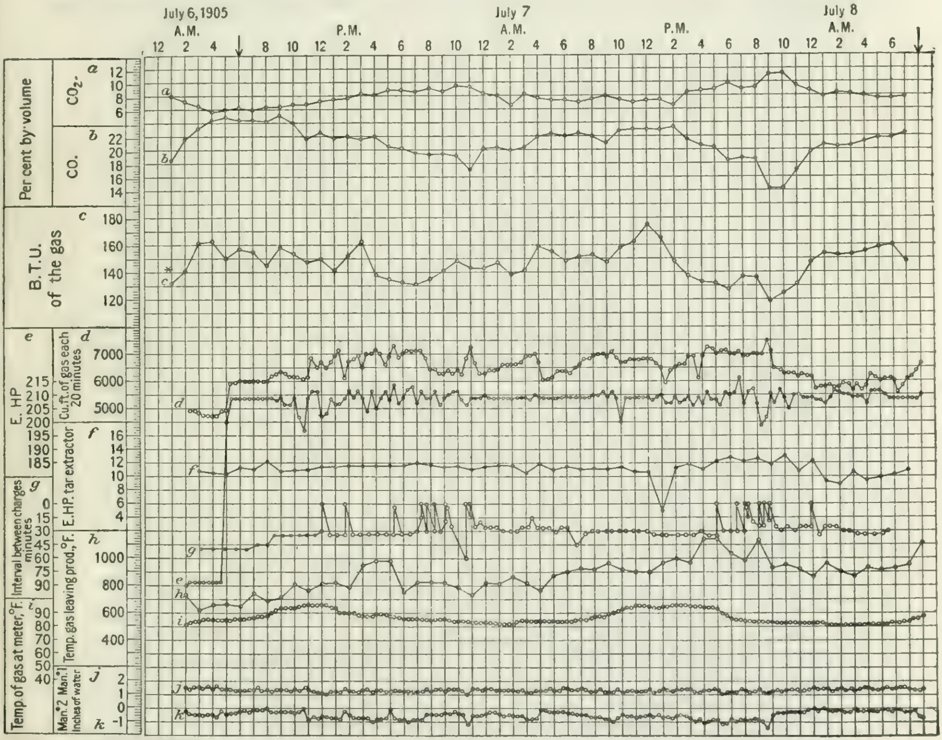
Right cylinder. M. E. P., 64; Max., 262; Rel., 24; I. H. P., 102.3.

Left cylinder. M. E. P., 56; Max., 262; Rel., 23; I. H. P., 89.4.

FIGURE 51.—Indicator cards, test No. 48, Illinois No. 11D coal. Scale of spring, 80; revolutions per minute, 202.7.

warm. The heat value of the gas decreased to about 110 B. t. u. per cubic foot, and was on the decline when the test stopped. A full 50-hour run was made with about four-fifths full load. The average heat value of the gas for the entire run was 132 B. t. u. per cubic foot. Graphic log is given on page 159.

Indiana No. 13, test 138.—The fuel used during this test was from the same lot of coal that was used in test 132, except that it was run over a screen of ½-inch mesh. Thus screened, the coal worked remarkably well throughout the run. At the end of the test the fuel bed was in excellent condition, and from all indications the test could have been continued indefinitely. Owing to lack of coal, the run lasted only 24 hours. The heat value of the gas was fairly uniform and averaged 148 B. t. u. per cubic foot. The gas meter was by-passed throughout the test. Graphic log is given on page 159.

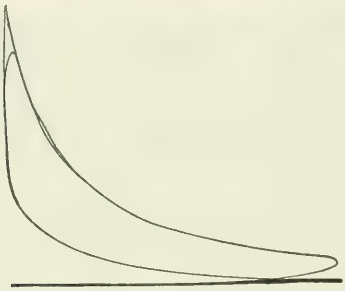


* Calculated B.T.U. plotted

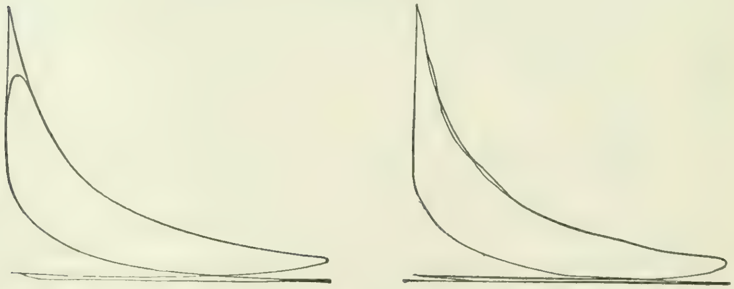
FIGURE 52.—Graphic log sheet, test No. 41, Illinois No. 13 coal.

Indiana No. 14, test 131.—Indiana No. 14 was a dirty coal containing considerable slack. It clinkered badly in the producer, but by careful watching the fuel bed was kept in fairly good condition during the entire test. The heat value of the gas was moderately uniform and averaged 154 B. t. u. per cubic foot. Approximately full load was carried during the 50-hour test. Graphic log is given on page 160.

Indiana No. 15, test 134.—Indiana No. 15, a clean-appearing run-of-mine coal, worked well in the producer. It had a slight tendency to fuse, but otherwise gave no trouble. The heat value of the gas was fairly uniform and averaged 144 B. t. u. per cubic foot. When the test was about half completed it became necessary to grind down the ashes; during this process the heat value of the gas decreased 15 to 20 B. t. u. per cubic foot. Soon after the heat value began to increase gradually, and finally returned to its normal figure. For 3 hours following the grinding down of the ashes the load was reduced to about two-thirds full load. The test lasted 50 hours. Graphic log is given on page 160.



Center cylinder. M. E. P., 68; Max., 294; Rel., 26; I. H. P., 108.8.



Right cylinder. M. E. P., 62; Max., 274; Rel., 29; I. H. P., 99.2.

Left cylinder. M. E. P., 68; Max., 304; Rel., 28; I. H. P., 108.8.

FIGURE 53.—Indicator cards, test No. 41, Illinois No. 13 coal. Scale of spring, 80; revolutions per minute, 203.

Indiana No. 15, test 137.—Indiana No. 15, a run-of-mine coal containing considerable slack, worked well in the producer. The test was started with a fuel bed about 3½ feet in thickness. The fuel bed required frequent poking, but otherwise the coal gave no trouble. The heat value of the gas was fairly uniform, averaging 146 B. t. u. per cubic foot. Approximately full load was carried throughout the test of 50 hours. Graphic log is given on page 161.

Indiana No. 16, test 130.—The fuel used in this test, Indiana No. 16, was a rather dirty-appearing coal containing considerable slack.

At the beginning of the test, conditions were favorable for a good run, but soon after the start the fuel bed became very hot, clinkers gave considerable trouble, and blowholes formed frequently around the edges of the bed. A great deal of poking was required, and once during the run the ash bed was ground down in an effort to improve conditions, but without success. The test was continued until a full 50-hour run was made. About 90 per cent of full load was carried. The heat value of the gas averaged 147 B. t. u. per cubic foot. Graphic log is given on page 161.

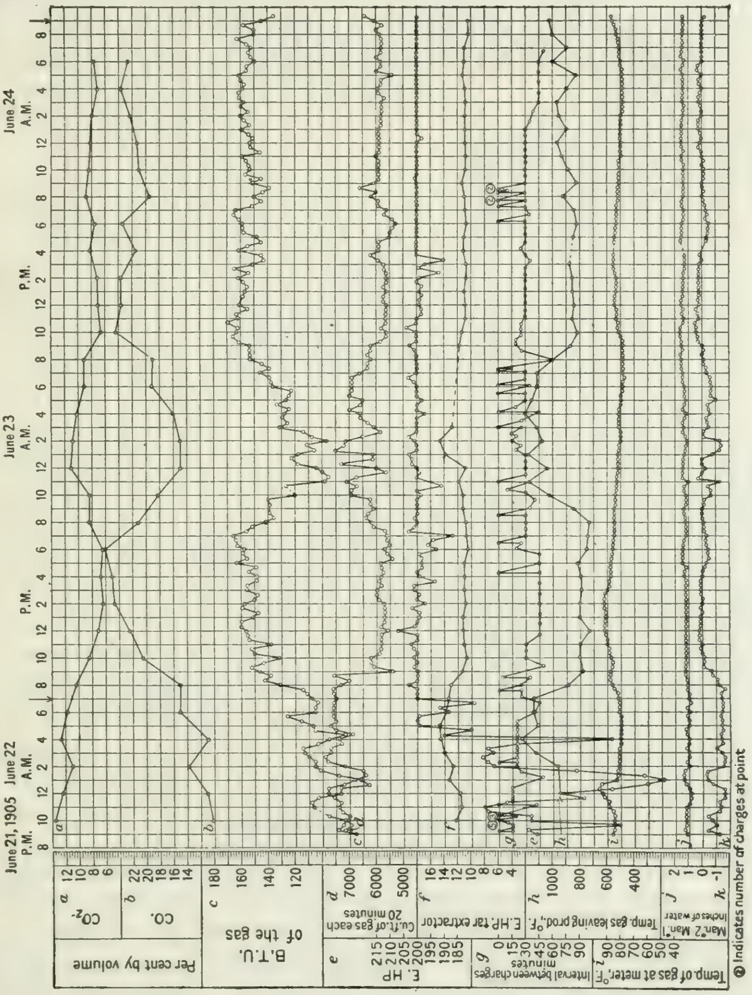
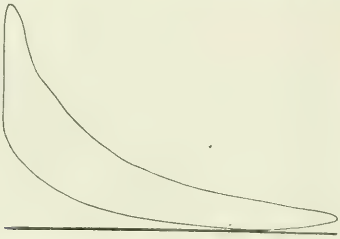


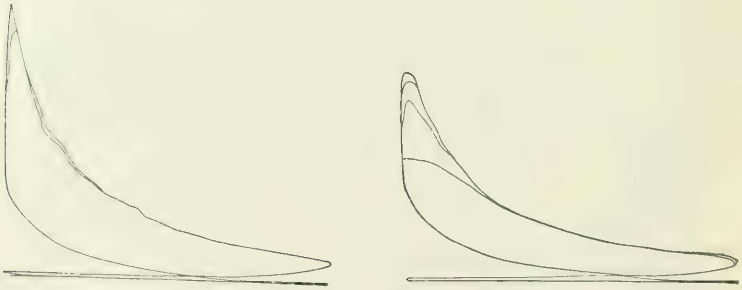
FIGURE 54.—Graphic log sheet, test No. 37, Illinois No. 14 coal.

Indiana No. 18B, test 133.—Indiana No. 18B, a clean, bright, lump coal, worked satisfactorily in the producer. The heat value of the gas was fairly uniform and averaged 155 B. t. u. per cubic foot. After 36 hours' run with approximately full load the test was abruptly brought to a close by an ell in the pipe line clogging with soot and tar. Graphic log is given on page 162.

Indiana No. 18B, test 135.—Indiana No. 18B, a lump coal, worked satisfactorily in the producer. The heat value of the gas was quite uniform and averaged 153 B. t. u. per cubic foot. During the last 3 hours of the test the tar extractor was out of use because of a broken belt, consequently the gas meter was by-passed to avoid any accumulation of tar in the meter. A full 50-hour test was made with approximately full load. Graphic log is given on page 162.



Center cylinder. M. E. P., 62; Max., 262; Rel., 27; I. H. P., 99.2.



Right cylinder. M. E. P., 61; Max., 284; Rel., 26; I. H. P., 102.4.

Left cylinder. M. E. P., 50; Max., 222; Rel., 28; I. H. P., 80.0.

FIGURE 55. Indicator cards, test No. 37, Illinois No. 14 coal. Scale of spring, 80; revolutions per minute, 203.0

INDIAN TERRITORY (OKLAHOMA).

Indian Territory No. 1, test 1.—This was a moderately free-burning coal. It coked fairly well in the producer and required but little attention. The coal was charged after being crushed and sized on a screen of ½-inch mesh. The screening was done while the coal was wet, and considerable slack stuck to the lumps. This coal may be considered a good producer fuel. Two and one-half barrels of tar were extracted during the test. Graphic log is given on page 163.

Indian Territory No. 4, test 20.—This coal burned well in the producer during the early part of the test, but the character of the fuel seemed to change suddenly to a lower grade, after which the operation of the producer was rather unsatisfactory and only partial load could be maintained. No trouble was experienced from clinker.

Fifty gallons of black tar were extracted. Graphic log is given on page 163.

IOWA.

Iowa No. 2, test 22.—The coal used in this test was high in sulphur (5.50 per cent), but did not clinker in the producer. The results were, however, not as satisfactory as might be expected. There is no doubt that better records could be made from this coal in a second test. The lack of uniformity in the quality of the gas made it difficult to adjust the engine to meet the changes. Fifty gallons of black tar were extracted. Graphic log is given on page 164.

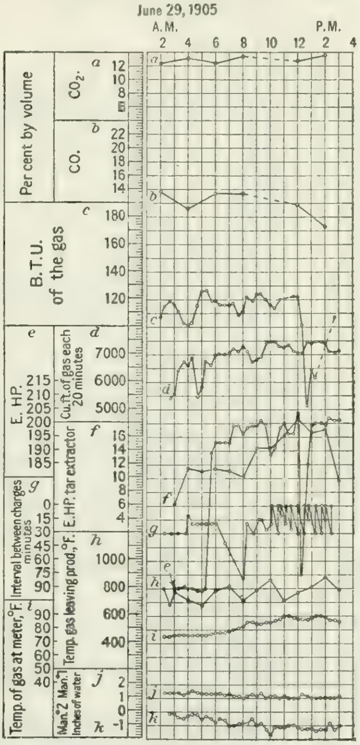


FIGURE 56.—Graphic log sheet, test No. 39, Illinois No. 15 coal.

KANSAS.

Kansas No. 5, test 24.—This coal was fed into the producer in the form of fine slack, and consequently it was difficult to handle with the automatic feeding device in use. It is, however, a fairly good producer fuel. Graphic log is given on page 164.

Kansas No. 5, test 25.—Kansas No. 5 coal, sized on a screen of ⅝-inch mesh, proved to be a fair gas-producer fuel, although the heat value of the gas averaged only 129 B. t. u. per cubic foot. There were no hard clinkers in the bed, and at no time during the 30-hour test was there any difficulty in making gas with which the engine could carry its full rated load. Graphic log is given on page 165.

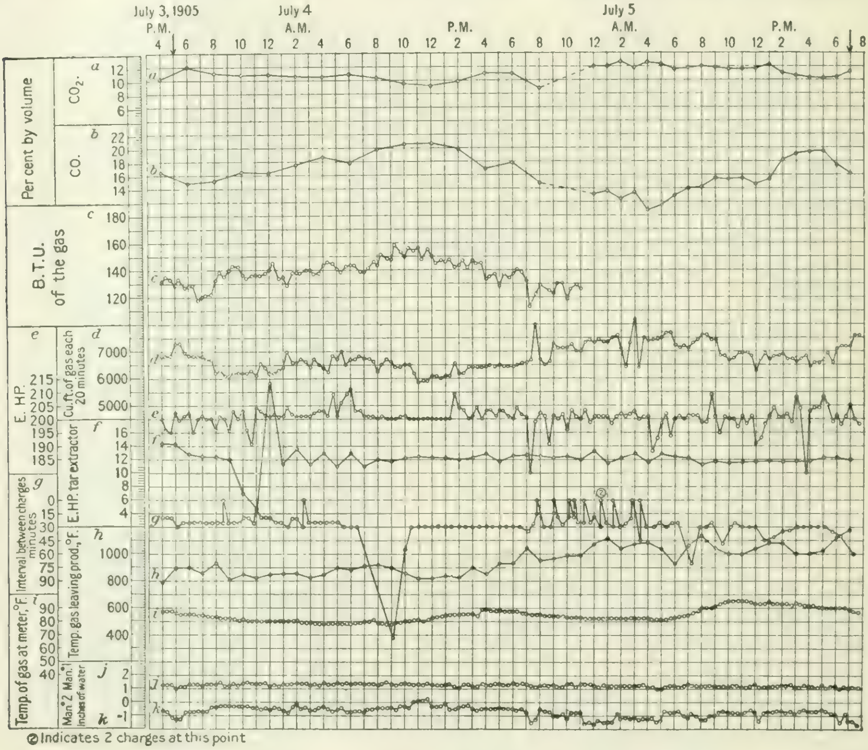
Kansas No. 6, test 101.—Owing to lack of coal, a test of only 13½ hours was made with this fuel. During this time, however, the producer worked well. The heat value of the gas was uniform and averaged 155 B. t. u. per cubic foot. The engine carried full load throughout the run. Graphic log is given on page 166.

KENTUCKY.

Kentucky No. 1B, test 79.—Kentucky No. 1B was a good coal for producer-gas generation, the size used, mostly from 1¾ inch to 3 inch, lending itself particularly well to proper handling in the producer. The heat value of the gas averaged 166.5 B. t. u. per cubic foot. The 50-hour test was easily completed, with the engine carrying full load. As there was no steaming test on this coal, the apparent evaporation of Kentucky No. 1C was used in the calculations. Graphic log is given on page 166.

Kentucky No. 3, test 12.—Kentucky No. 3 was a hard bituminous coal, and formed a hard top crust in the producer. It yielded a gas of uniformly good quality and 100 gallons of clean black tar. It is well adapted to the generation of producer gas. Graphic log is given on page 167.

Kentucky No. 5, test 81.—Kentucky No. 5 proved to be a satisfactory producer-gas fuel. The fuel bed worked easily and no clinkers formed. The heat value of the gas was fairly uniform, and averaged 163 B. t. u. per cubic foot. The complete 50-hour run was made with full load. Graphic log is given on page 167.



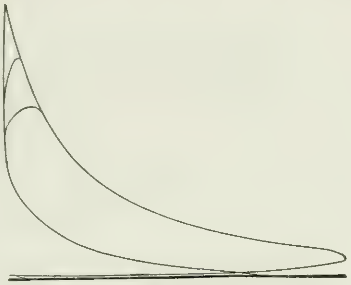
② Indicates 2 charges at this point

FIGURE 57.—Graphic log sheet, test No. 40, Illinois No. 15 coal.

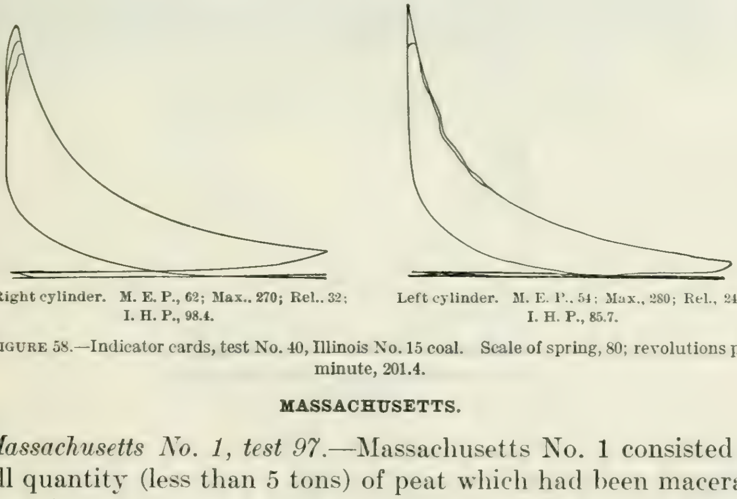
Kentucky No. 6, test 85.—Kentucky No. 6 was a very hard bituminous coal, in some particulars resembling cannel, but containing less oil. In other respects it acted like lignite. It worked excellently and yielded a gas the heat value of which at times ran as high as 190 B. t. u. and averaged 176 B. t. u. per cubic foot. The gas had a smell similar to lignite gas, and the tar was yellow.

There was a slight tendency of the bed to become too hot, and during part of the test cold air was taken into the blast pipe. No clinker of any consequence formed. Graphic log is given on page 168.

Kentucky No. 7, test 84.—Kentucky No. 7 proved to be a first-class producer fuel. It worked well in the producer, the fuel bed was cool, and no bad clinkers formed. Preheated air was used during the entire test. The heat value of the gas averaged 154 B. t. u. per cubic foot. The required 50-hour test was completed with ease, the engine carrying full load. Graphic log is given on page 168.



Center cylinder. M. E. P., 60; Max., 280; Rel., 32; I. H. P., 95.3.



Right cylinder. M. E. P., 62; Max., 270; Rel., 32; I. H. P., 98.4.

Left cylinder. M. E. P., 54; Max., 280; Rel., 24; I. H. P., 85.7.

FIGURE 58.—Indicator cards, test No. 40, Illinois No. 15 coal. Scale of spring, 80; revolutions per minute, 201.4.

MASSACHUSETTS.

Massachusetts No. 1, test 97.—Massachusetts No. 1 consisted of a small quantity (less than 5 tons) of peat which had been macerated, pressed into bricks, and then dried. Lack of fuel made it impossible to run a test of sufficient length to eliminate the factor of uncertainty, but the test proved that a satisfactory gas could be obtained, and no trouble was experienced in manipulating the fuel bed or in maintaining the load. On account of the small supply of peat, it was necessary to make the foundation of the fuel bed out of another fuel (Illinois coal), and it is impossible to tell exactly the respective proportions of the gas derived from the coal and from the peat. The figures are presented, however, for what they are worth,

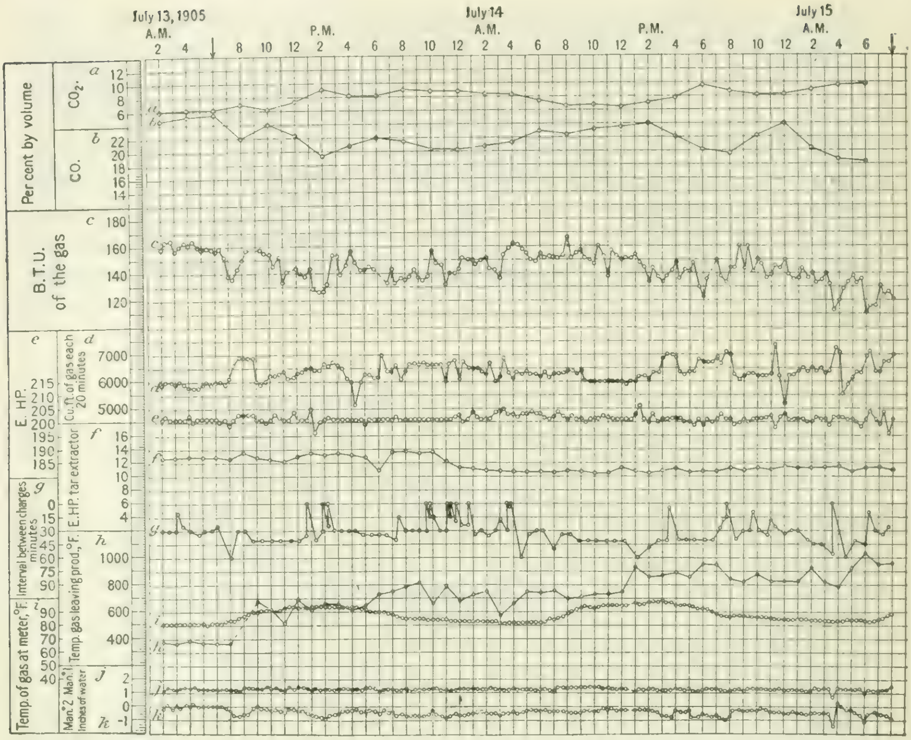
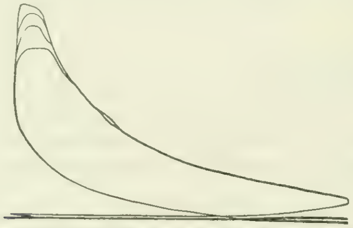
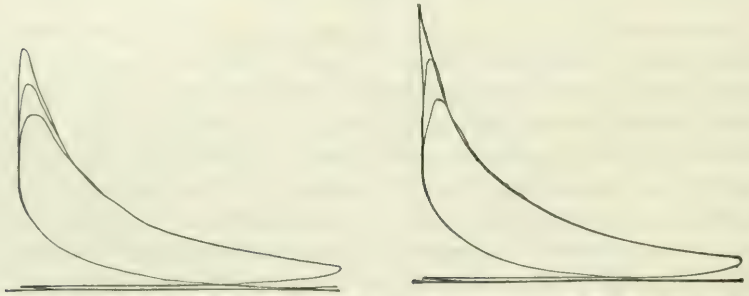


FIGURE 59.—Graphic log sheet, test No. 43, Illinois No. 16 coal.



Center cylinder. M. E. P., 64; Max., 230; Rel., 40;
I. H. P., 102.7.



Right cylinder. M. E. P., 60; Max., 240; Rel., 28;
I. H. P., 96.3.

Left cylinder. M. E. P., 60; Max., 280; Rel., 32;
I. H. P., 96.3.

FIGURE 60.—Indicator cards, test No. 43, Illinois No. 16 coal. Scale of spring, 80; revolutions per minute, 203.8.

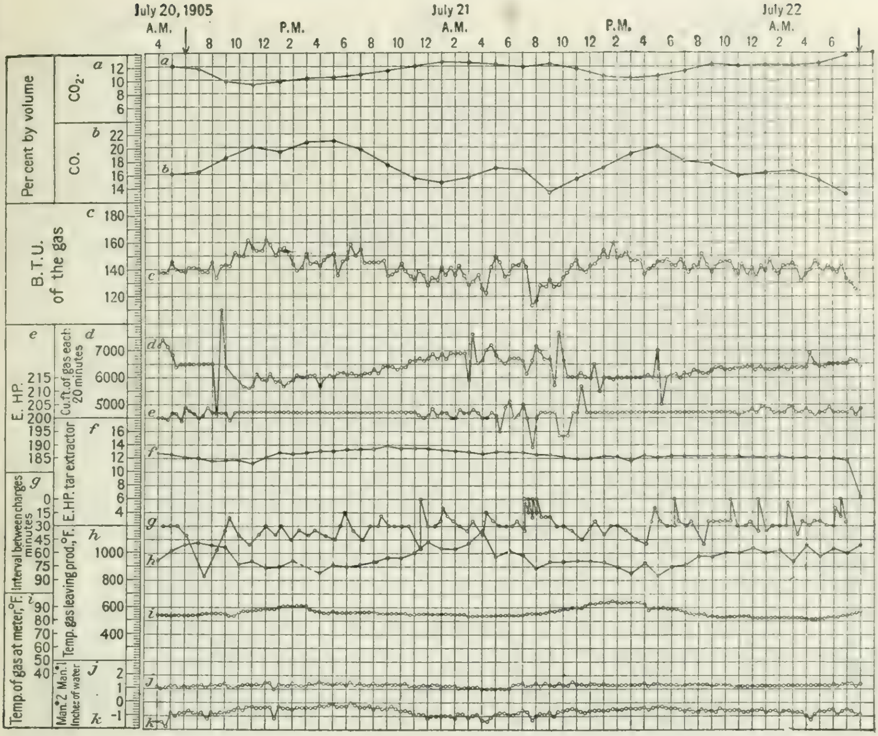
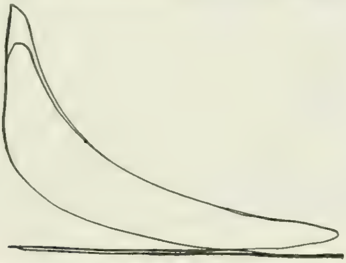
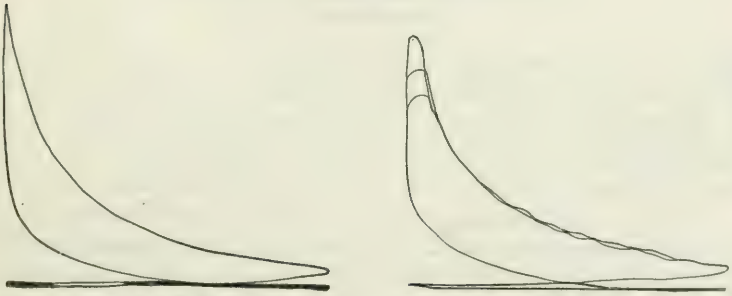


FIGURE 61.—Graphic log sheet, test No. 45, Illinois No. 18 coal.



Center cylinder. M. E. P., 70; Max., 264; Rel., 30;
I. H. P., 112.4.



Right cylinder. M. E. P., 60; Max., 296; Rel.,
22; I. H. P., 96.3.

Left cylinder. M. E. P., 62; Max., 274; Rel., 30;
I. H. P., 99.6.

FIGURE 62.—Indicator cards, test No. 45, Illinois No. 18 coal. Scale of spring, 80; revolutions per minute, 203.8.

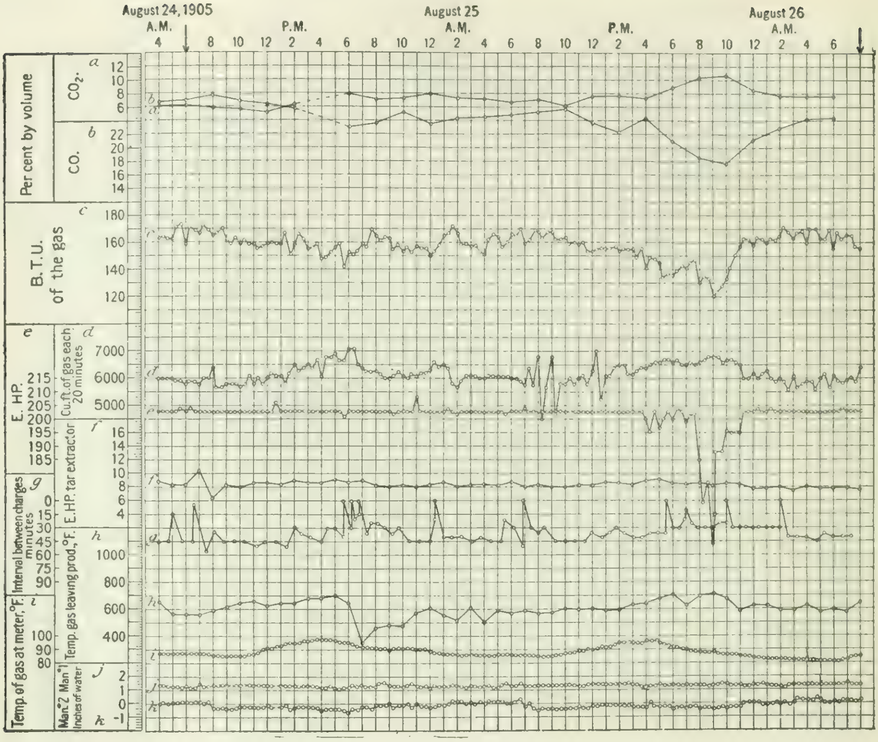
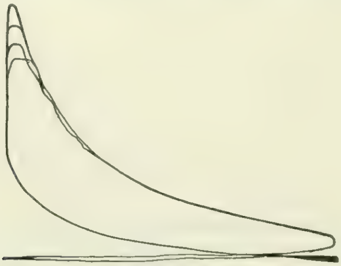
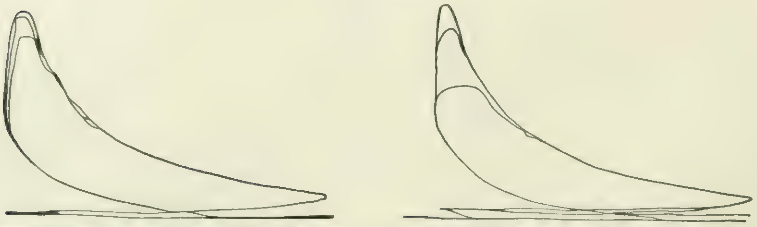


FIGURE 63.—Graphic log sheet, test No. 55, Illinois No. 19B coal.



Center cylinder. M. E. P., 70; Max., 280; Rel., 40; I. H. P., 112.6.



Right cylinder. M. E. P., 60; Max., 230; Rel., 34; I. H. P., 96.6.

Left cylinder. M. E. P., 58; Max., 240; Rel., 34; I. H. P., 93.4.

FIGURE 64.—Indicator cards, test No. 55, Illinois No. 19B coal. Scale of spring, 80; revolutions per minute, 204.2.

as they furnish an approximate idea of the possibilities of peat fuel in the gas producer. Graphic log is given on page 169.

MISSOURI.

Missouri No. 2, test 7A and 7B.—In using Missouri No. 2 coal some difficulty was experienced in keeping the fuel bed in good condition, due to its tendency to break open in spots. Graphic log is given on page 169.

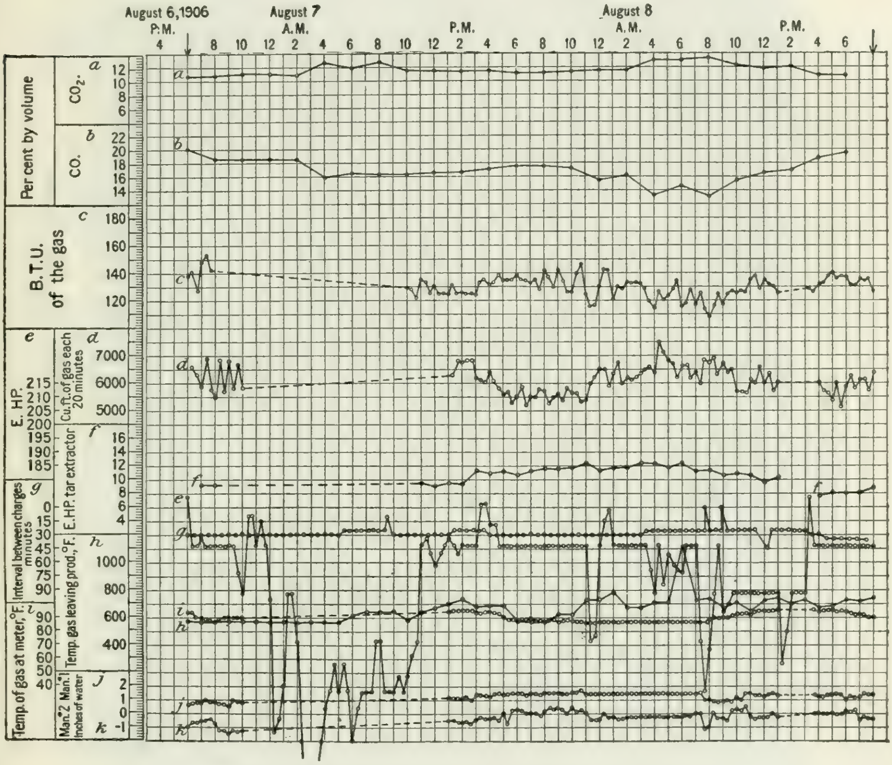


FIGURE 65.—Graphic log sheet, test No. 128, Illinois No. 19C coal.

MONTANA.

Montana No. 1, test 5A and 5B.—Montana No. 1 coal was a washed slack. It made gas of good quality, but was too fine to be burned at the rated output of the producer. It clinkered badly, causing bad blowholes in the fuel bed. The test is valuable principally as a demonstration that a good quality of gas can be made from coal of this class. Graphic log is given on page 169.

Montana No. 2, test 149.—Montana No. 2, a dull subbituminous coal, worked well in the producer and without any indication of clinker. In the early part of the test a high ash bed gave considerable trouble, in consequence of which the gas was rather low and variable

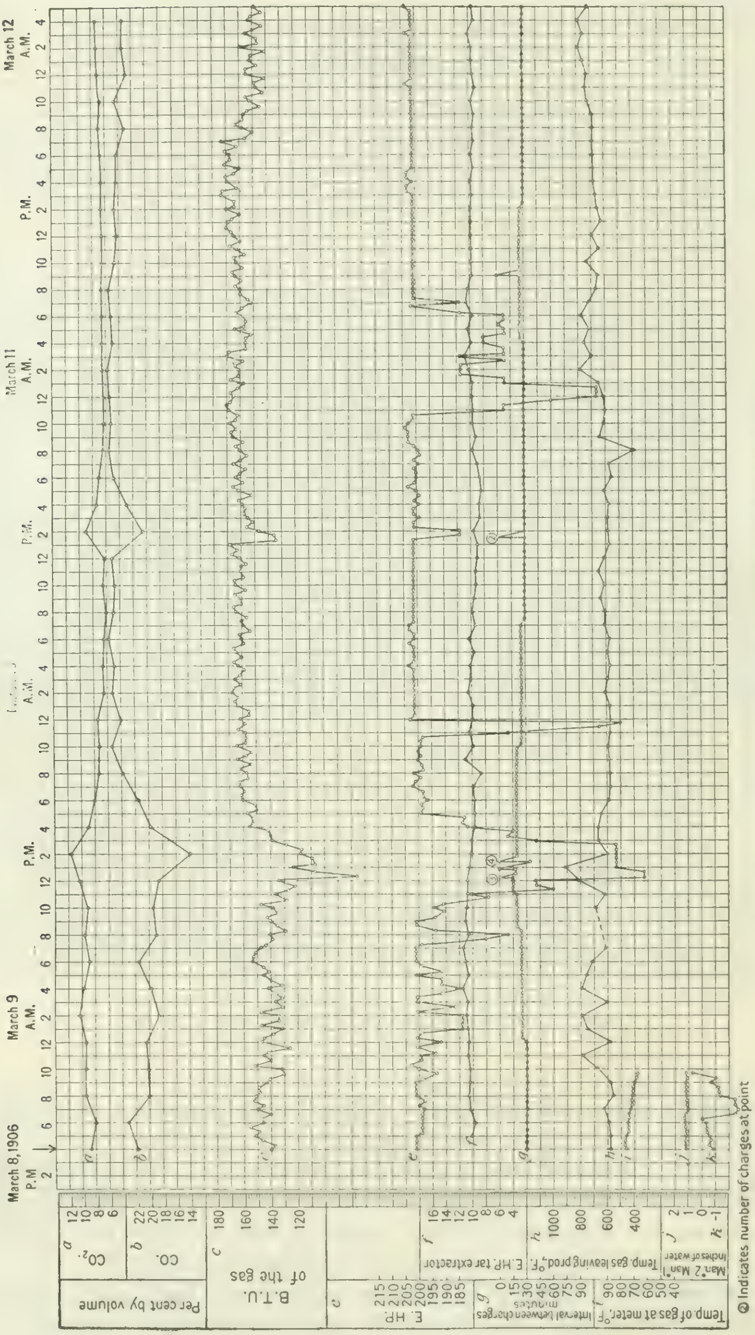


FIGURE 66.—Graphic log sheet, test No. 105, Illinois No. 21 coal.

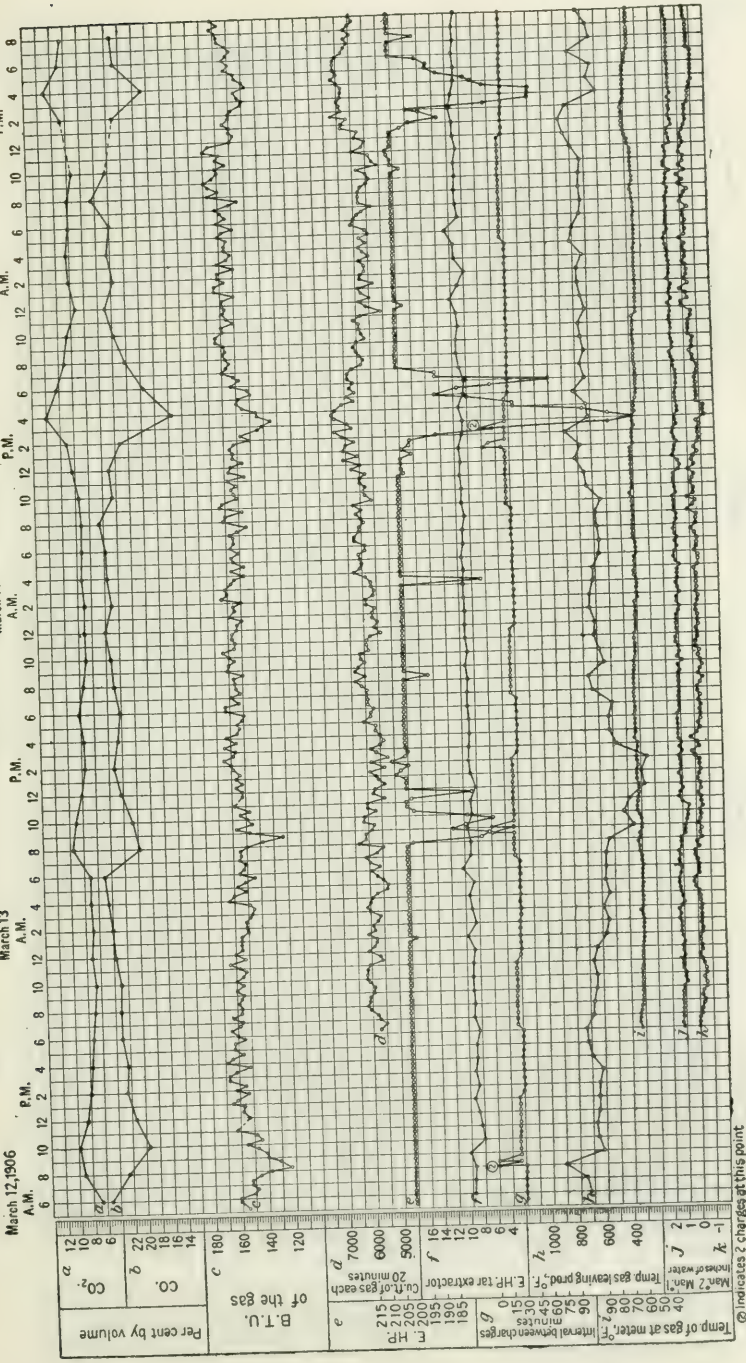


FIGURE 67.—Graphic log sheet, test No. 105, Illinois No. 21 coal.

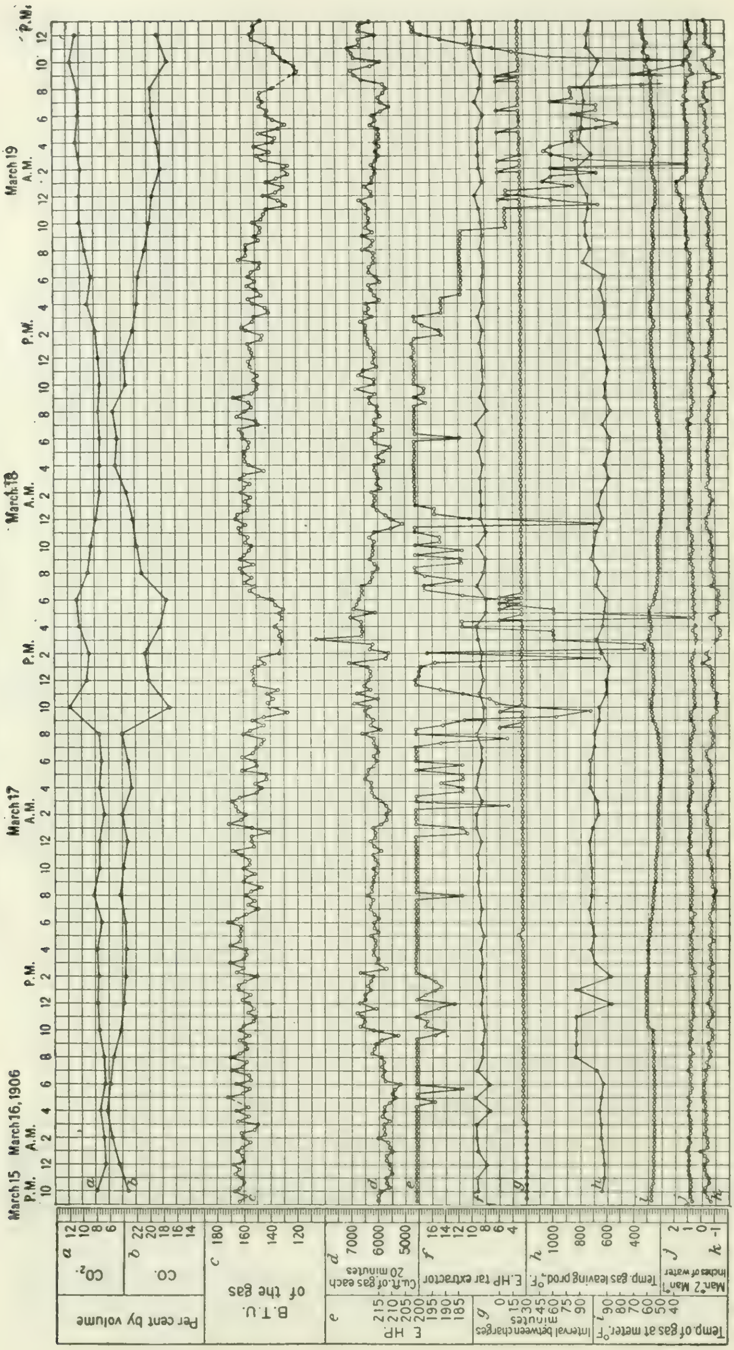


FIGURE 68.—Graphic log sheet, test No. 105, Illinois No. 21 coal.

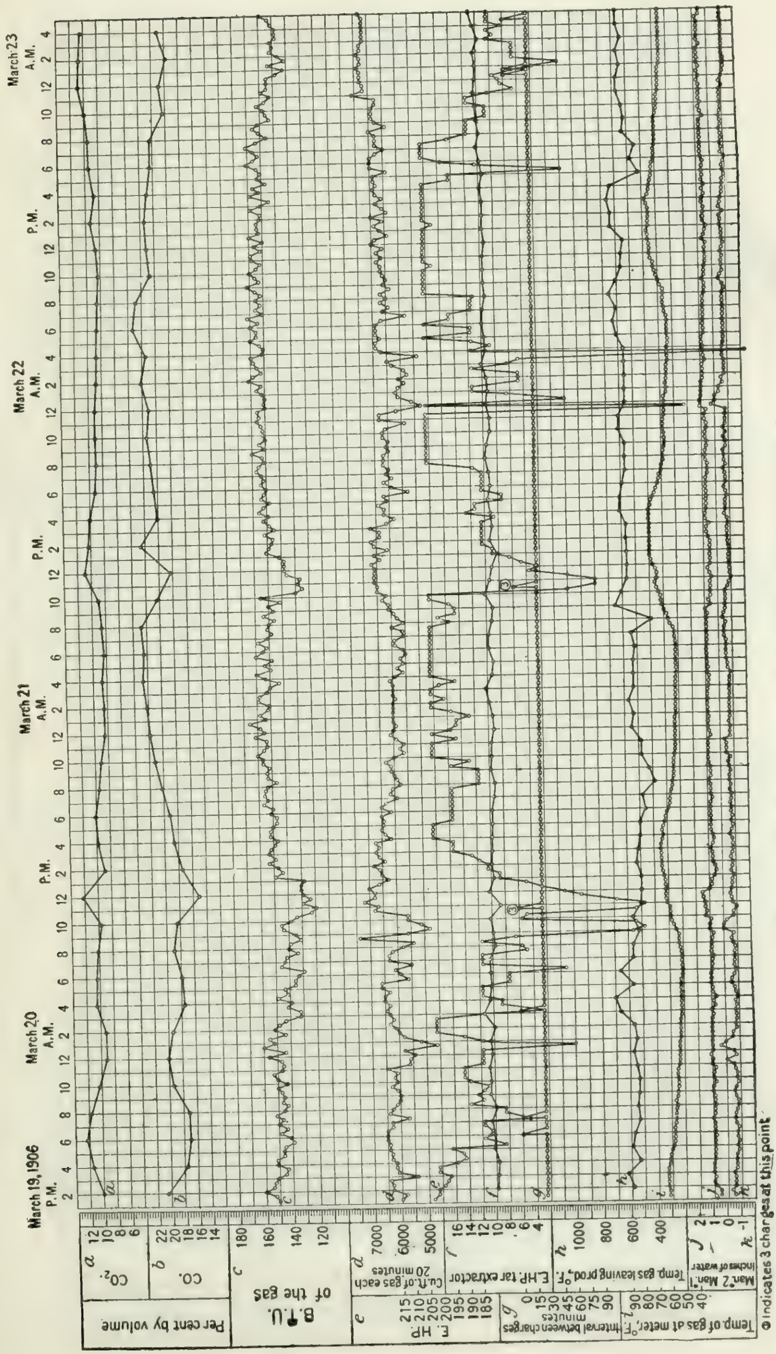


FIGURE 69.—Graphic log sheet, test No. 105, Illinois No. 21 coal.

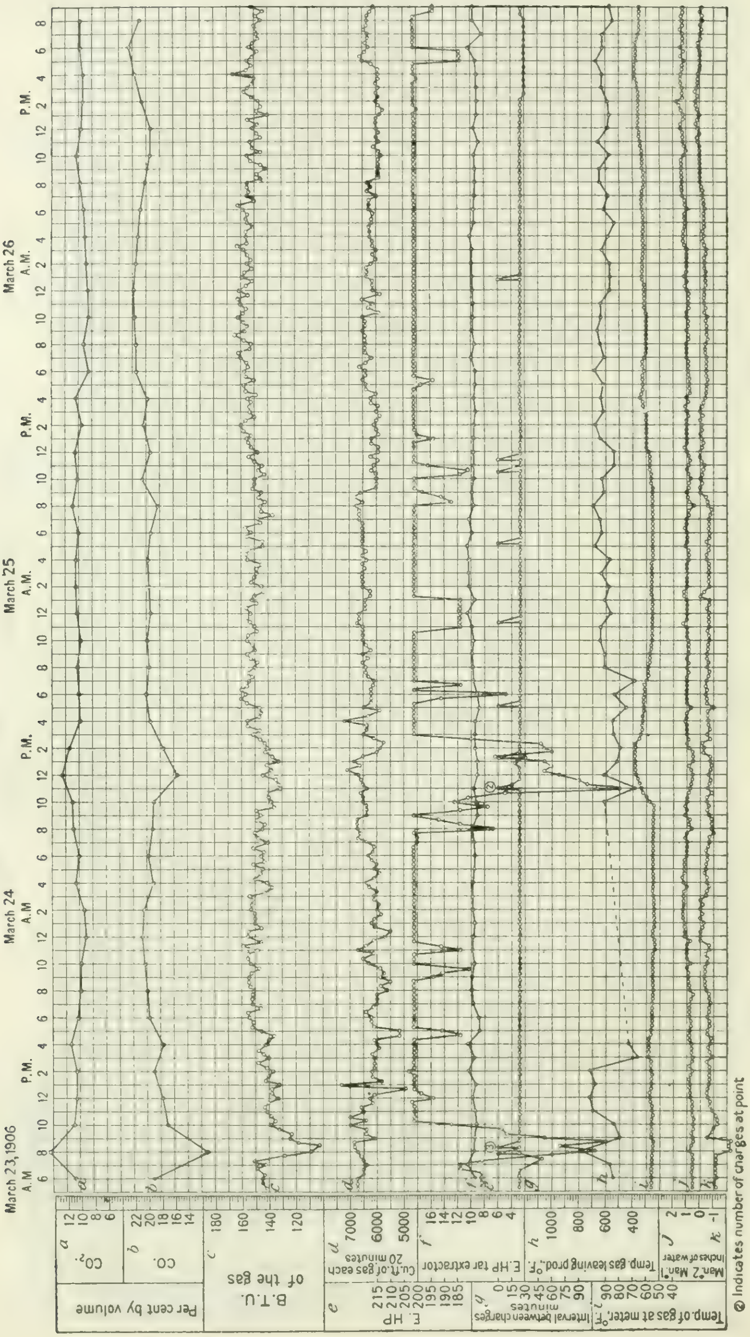


FIGURE 70.—Graphic log sheet, test No. 105, Illinois No. 21 coal.
]

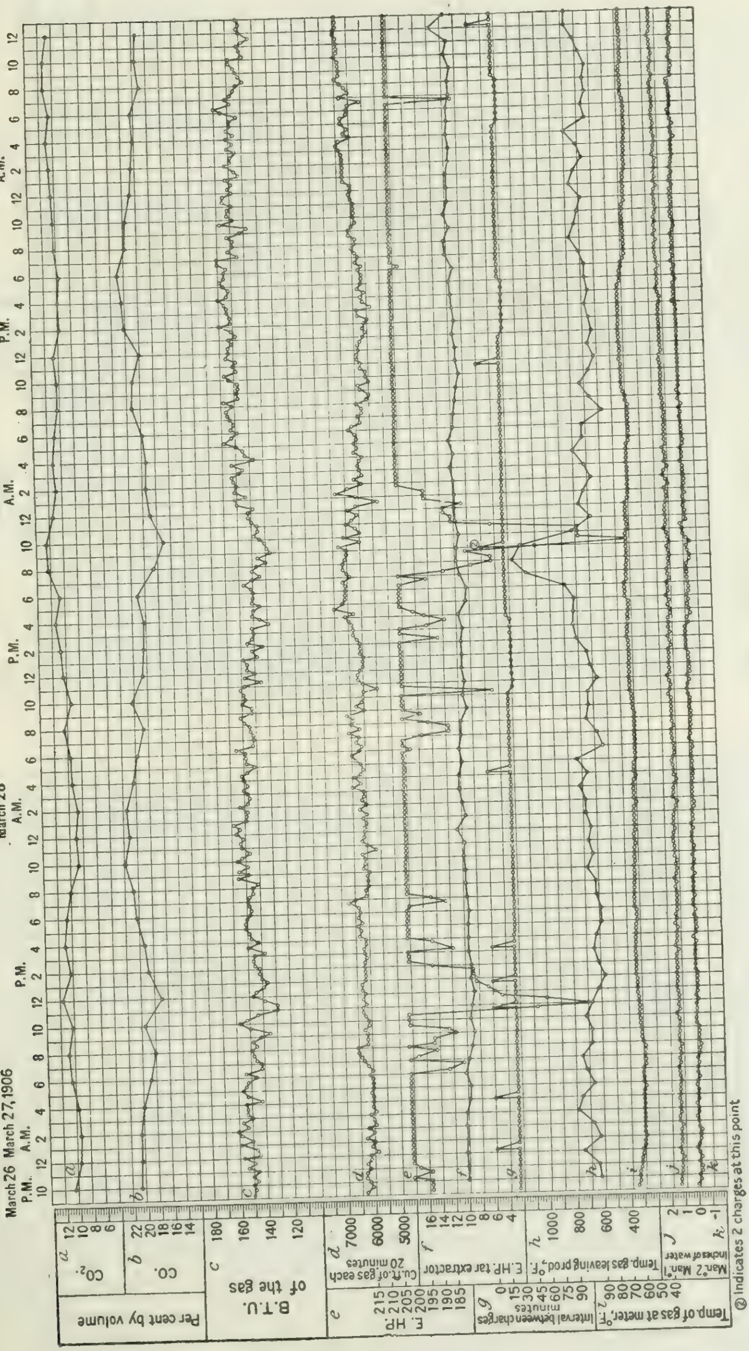


FIGURE 71.—Graphic log sheet, test No. 105, Illinois No. 21 coal.

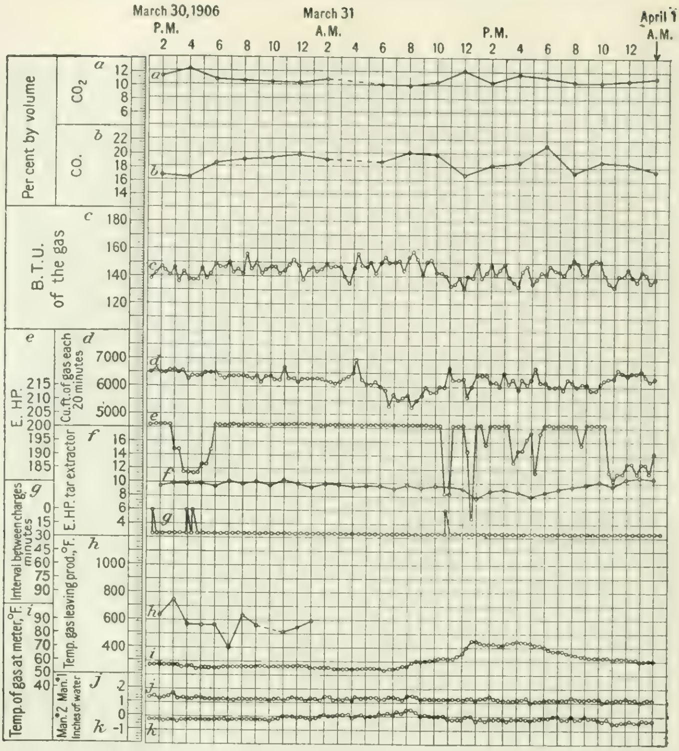
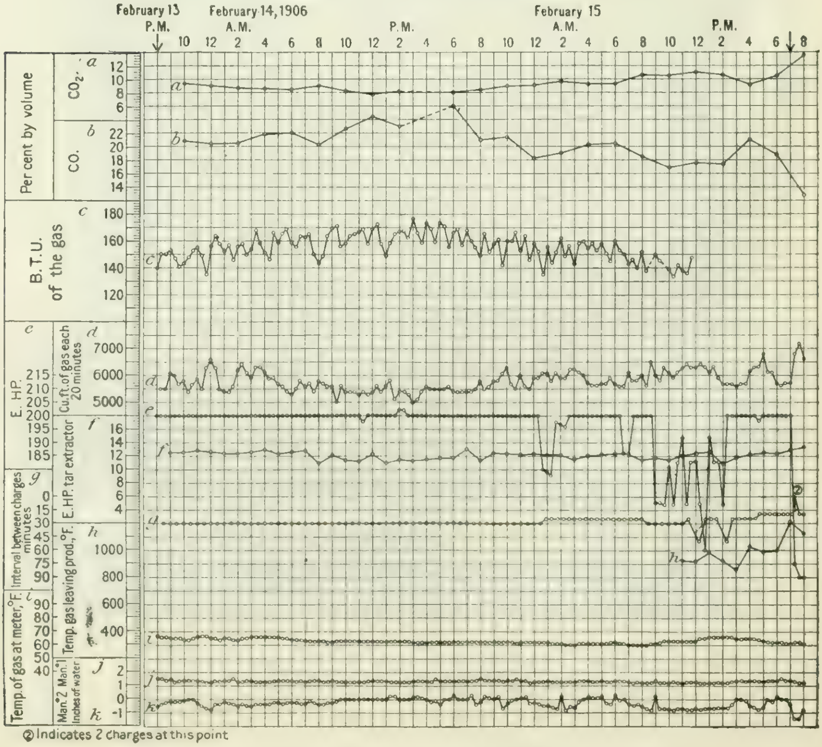


FIGURE 72.—Graphic log sheet, test No. 105, Illinois No. 21 coal.



② Indicates 2 charges at this point

FIGURE 73.—Graphic log sheet, test No. 102, Illinois No. 22A coal.

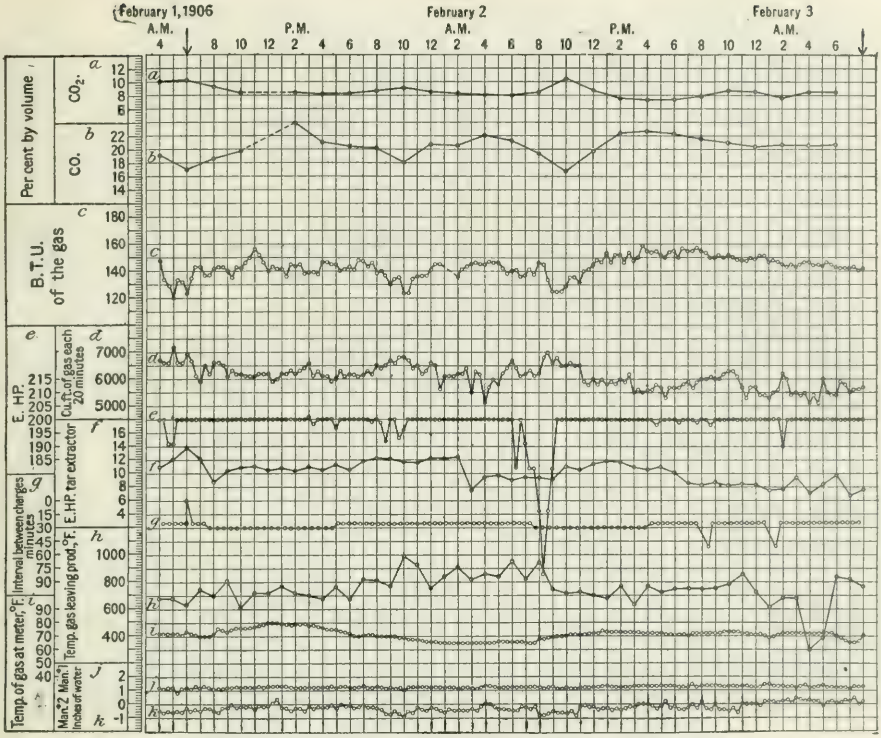


FIGURE 74.—Graphic log sheet, test No. 98, Illinois No. 23A coal.

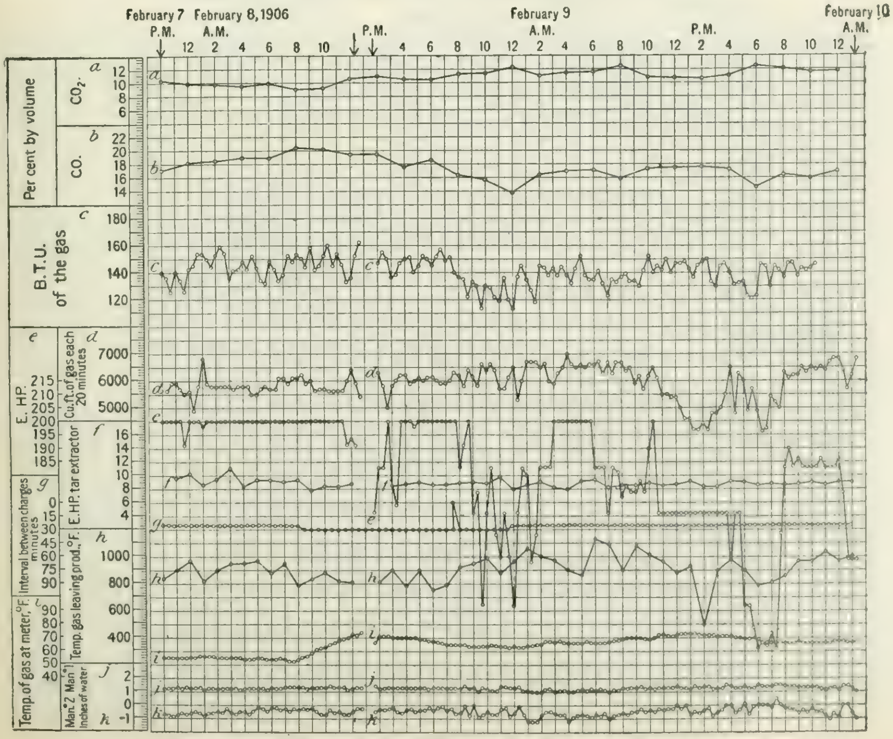


FIGURE 75.—Graphic log sheet, test No. 100, Illinois No. 23B coal.

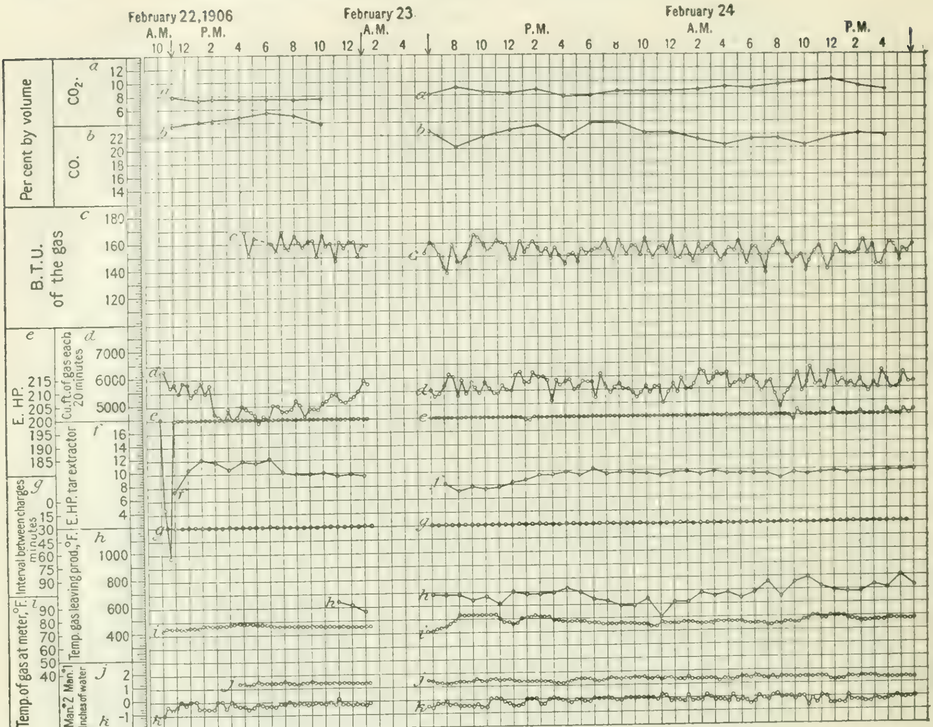


FIGURE 76.—Graphic log sheet, test No. 103, Illinois No. 24B coal.

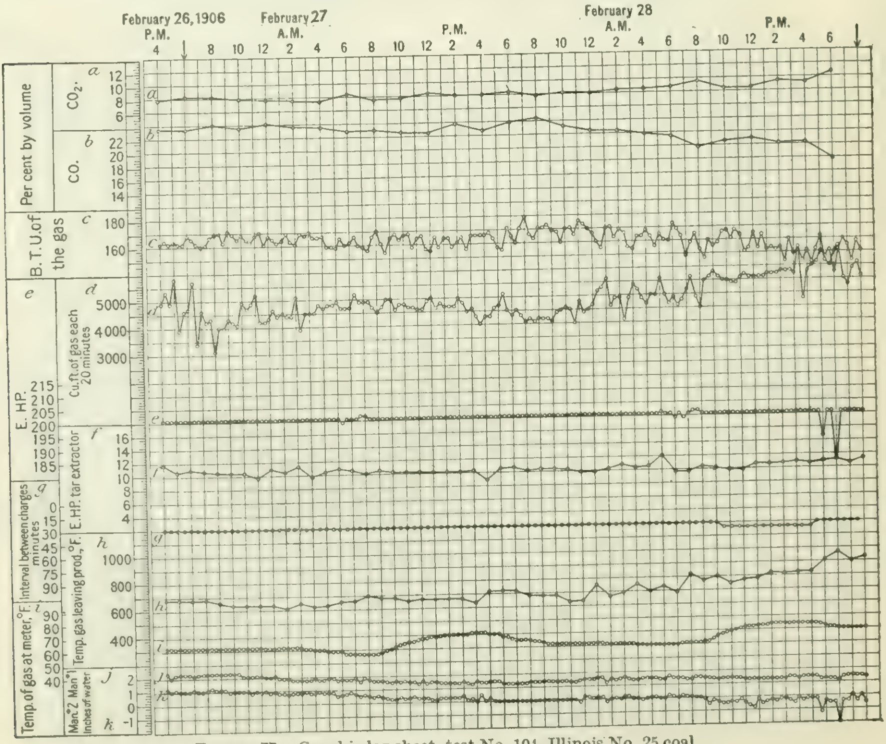


FIGURE 77.—Graphic log sheet, test No. 104, Illinois No. 25 coal.

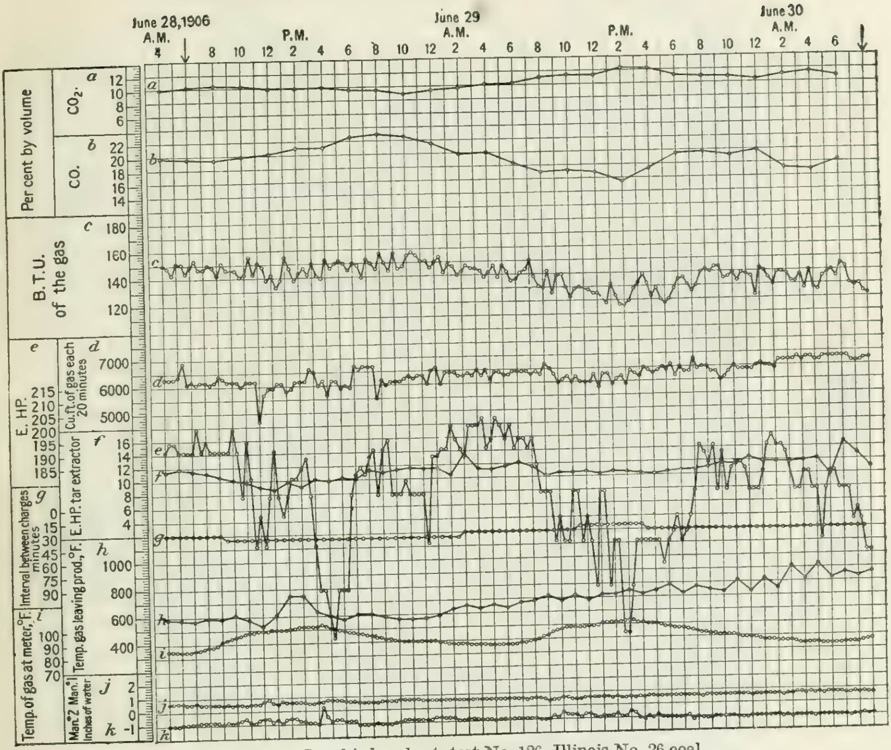
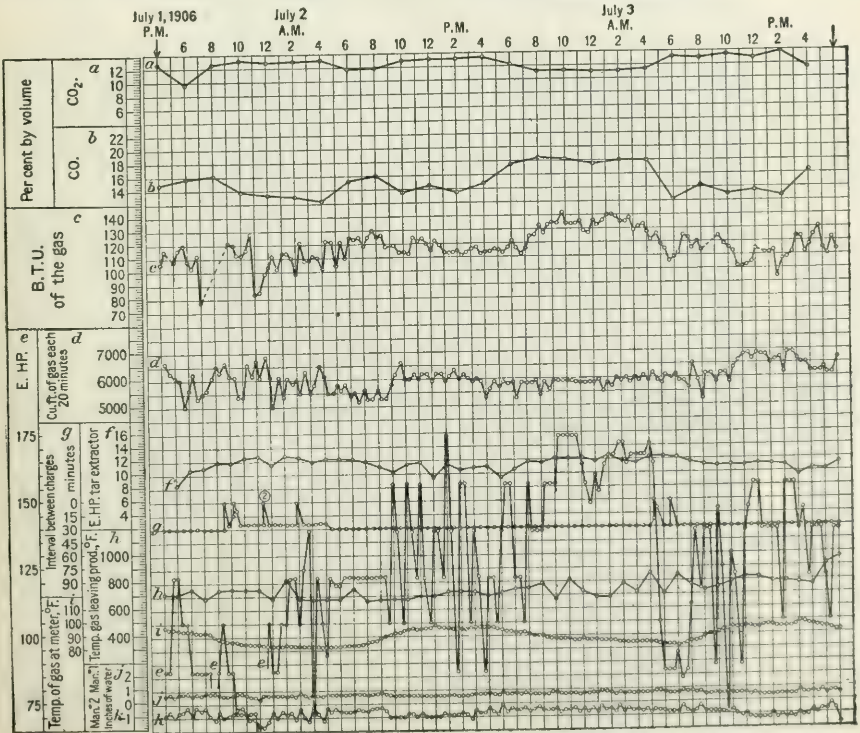


FIGURE 78.—Graphic log sheet, test No. 126, Illinois No. 26 coal.



② Indicates 2 charges at this point

FIGURE 79.—Graphic log sheet, test No. 127, Illinois No. 27 coal.

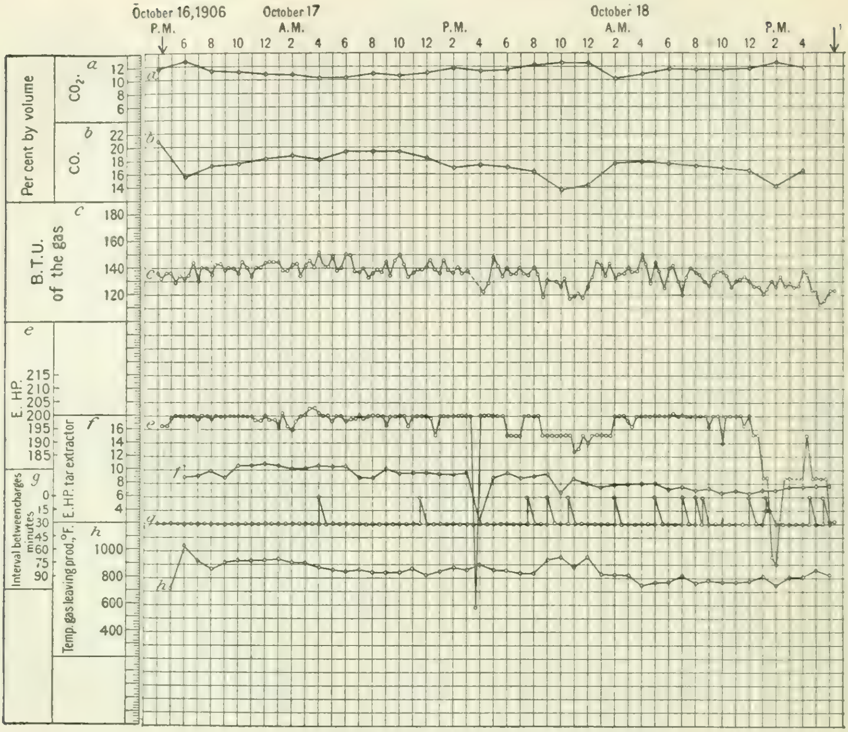
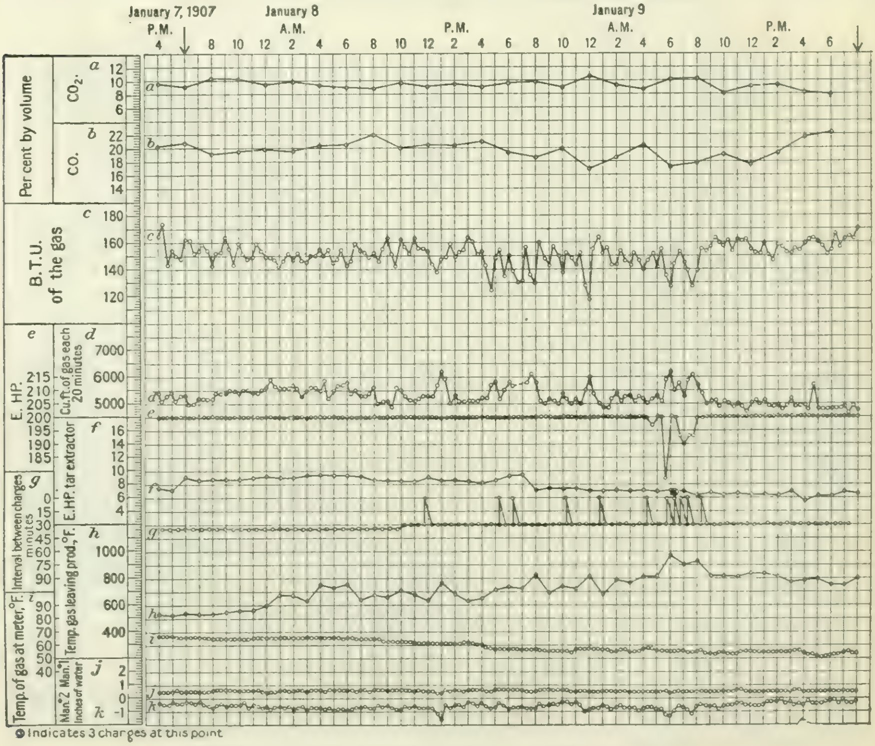


FIGURE 80.—Graphic log sheet, test No. 139, Illinois No. 29B coal.



● Indicates 3 charges at this point

FIGURE 81.—Graphic log sheet, test No. 157, Illinois No. 30 coal.

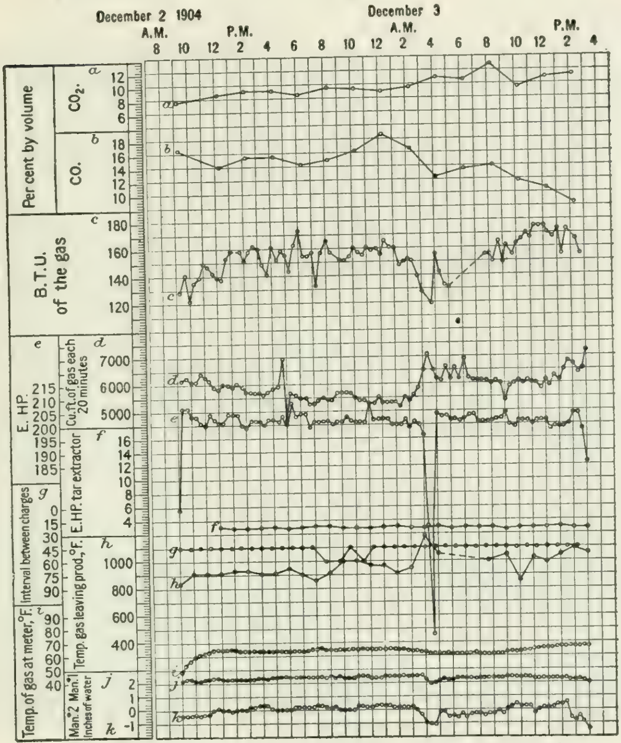


FIGURE 82.—Graphic log sheet, test No. 14, Indiana No. 1 coal.

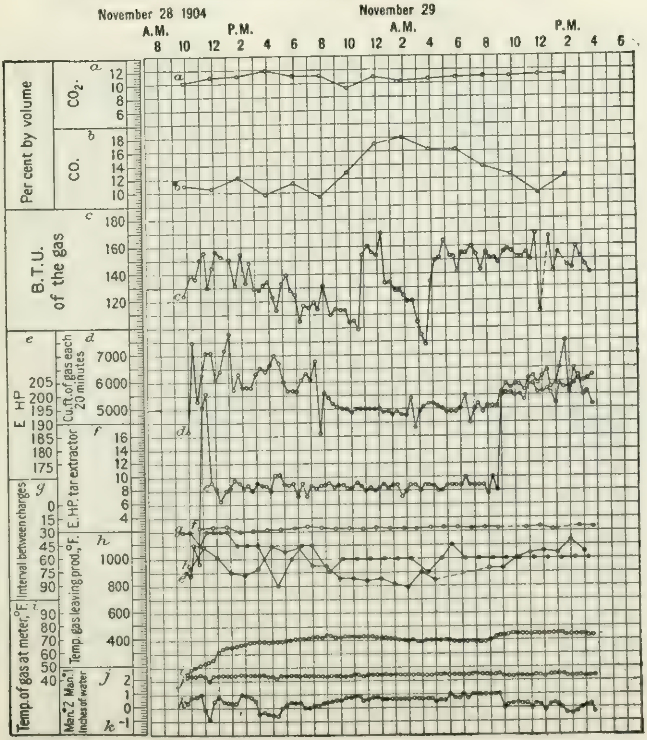
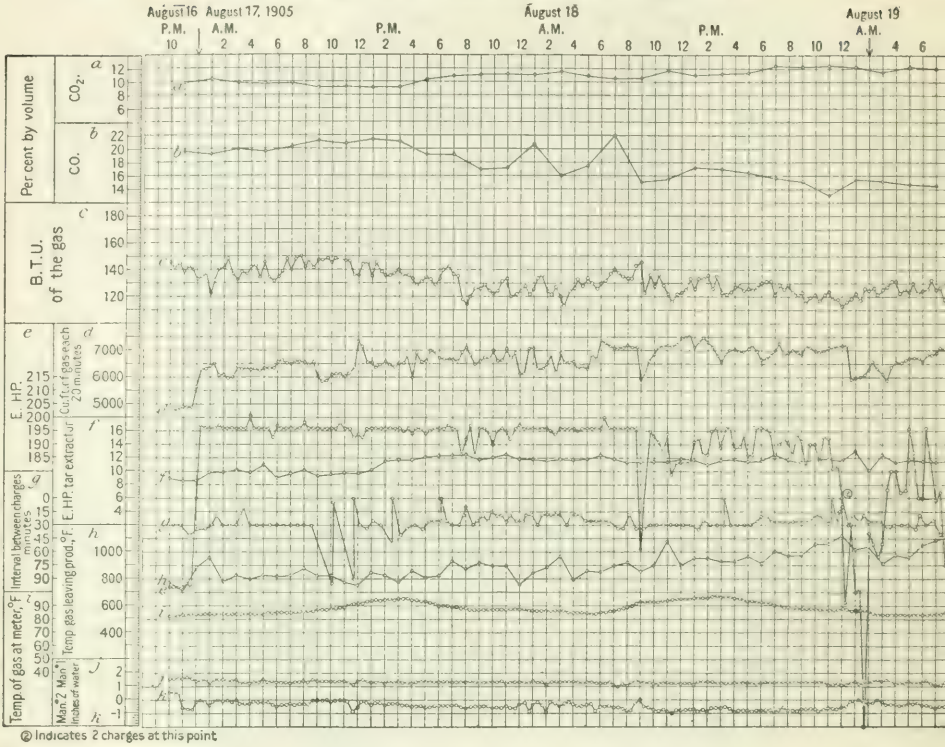
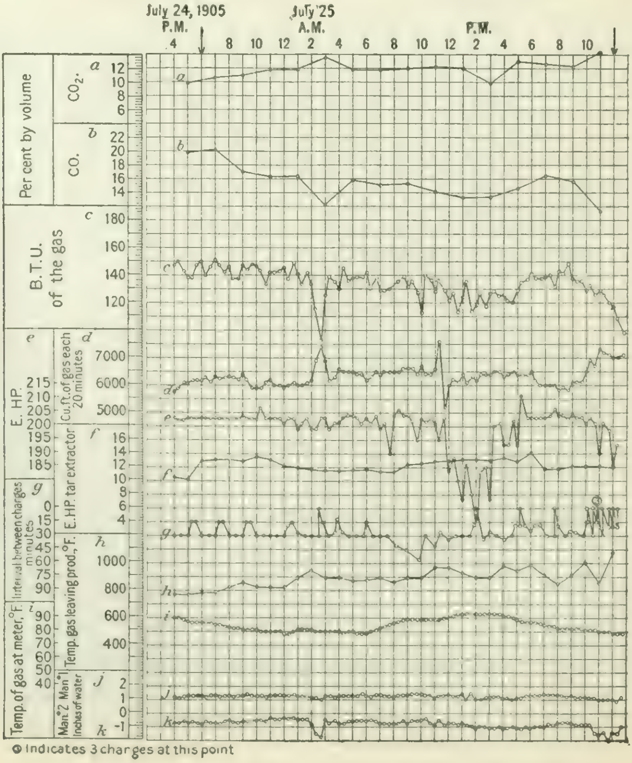


FIGURE 83.—Graphic log sheet, test Nos. 13A and 13B Indiana No. 2 coal.



② Indicates 2 charges at this point

FIGURE 84.—Graphic log sheet, test No. 53, Indiana No. 3 coal.



⊙ Indicates 3 charges at this point

FIGURE 85.—Graphic log sheet, test No. 46, Indiana No. 5 coal.

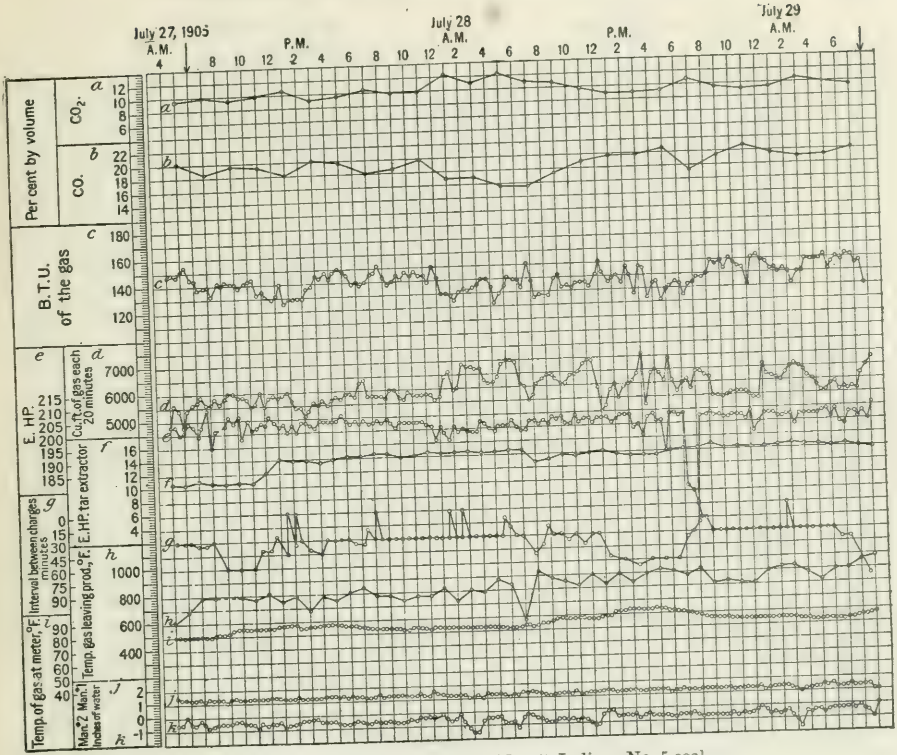


FIGURE 86.—Graphic log sheet, test No. 47, Indiana No. 5 coal.

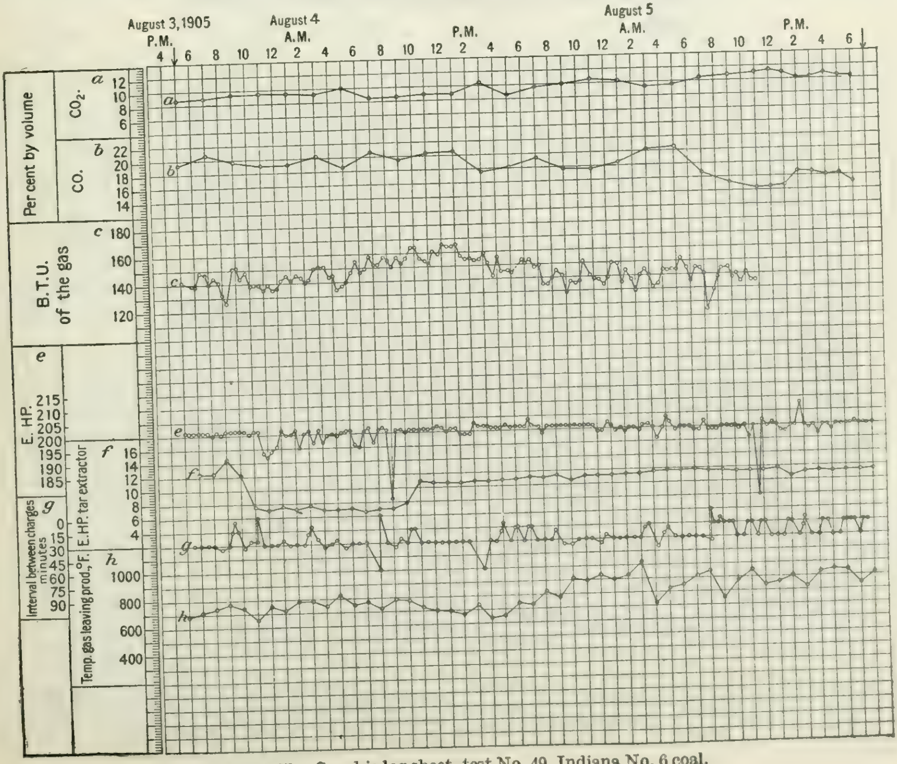


FIGURE 87.—Graphic log sheet, test No. 49, Indiana No. 6 coal.

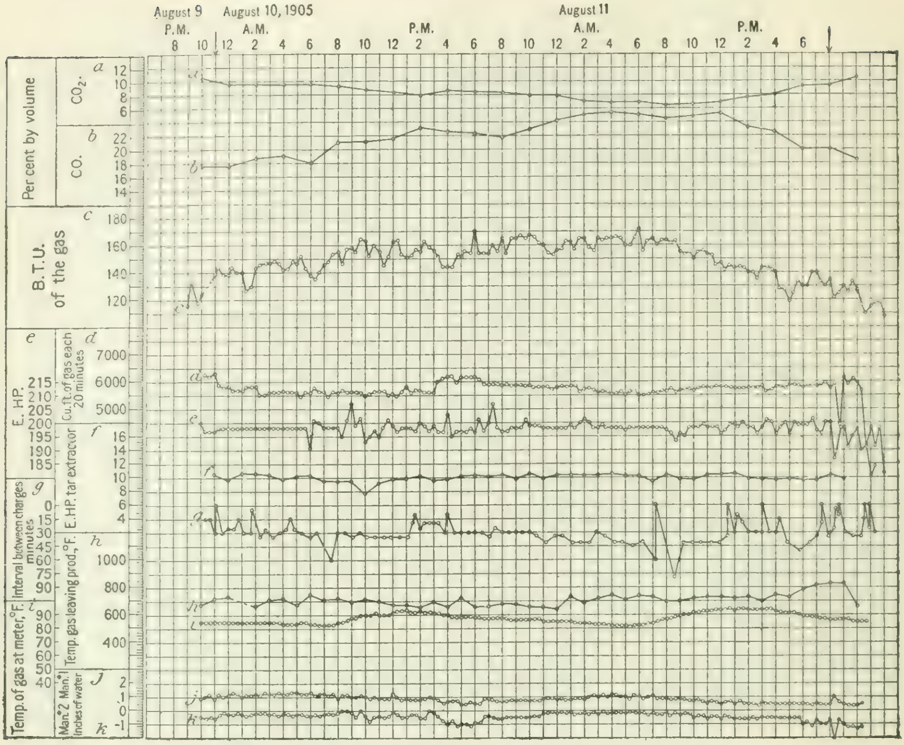
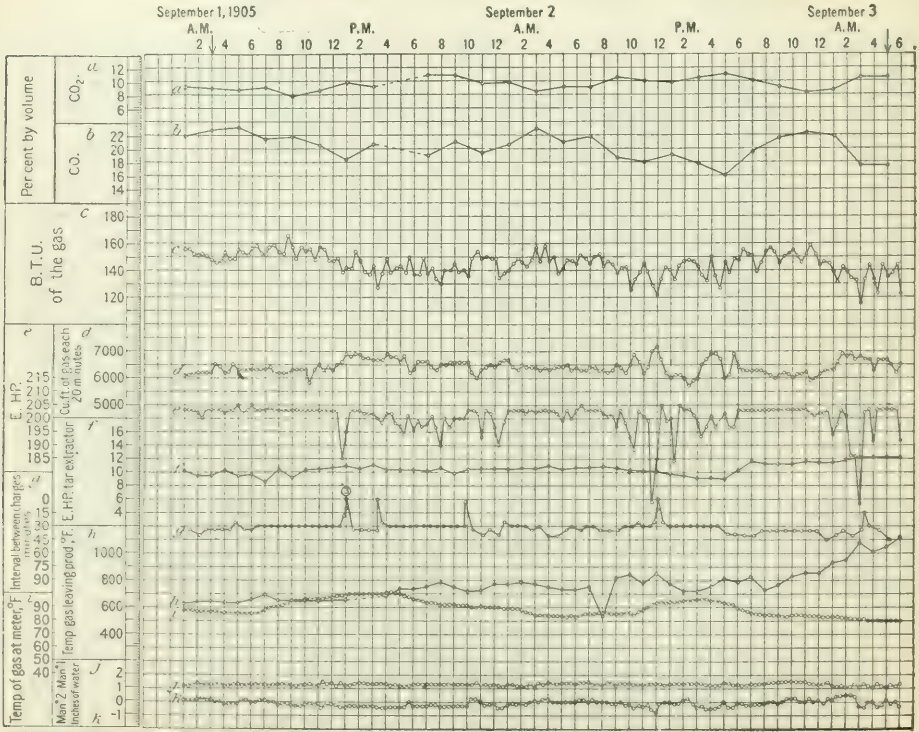


FIGURE 88.—Graphic log sheet, test No. 51, Indiana No. 7A coal.



⊙ Indicates 3 charges at this point

FIGURE 89.—Graphic log sheet, test No. 57, Indiana No. 8 coal.

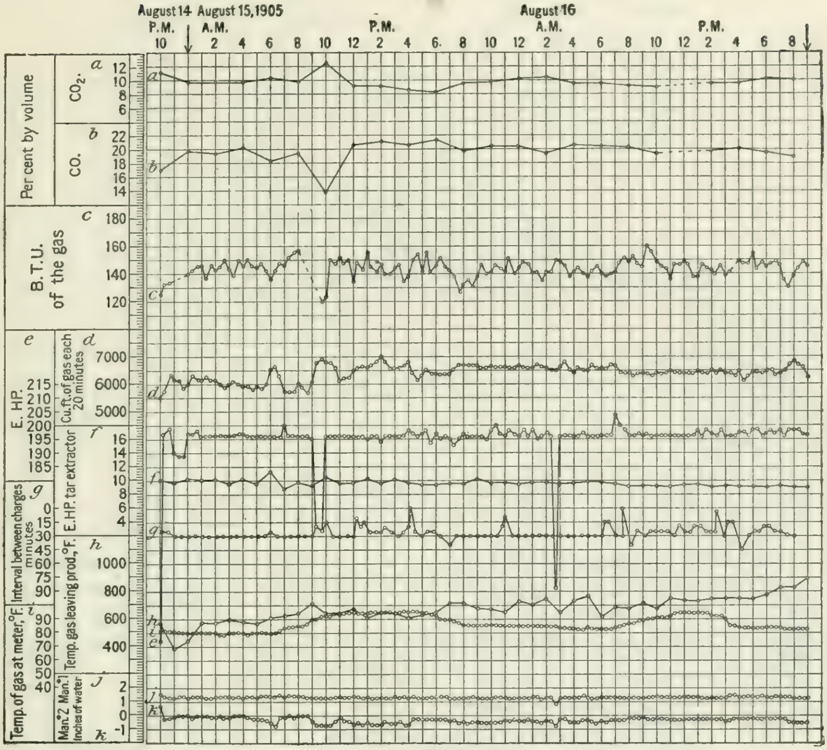
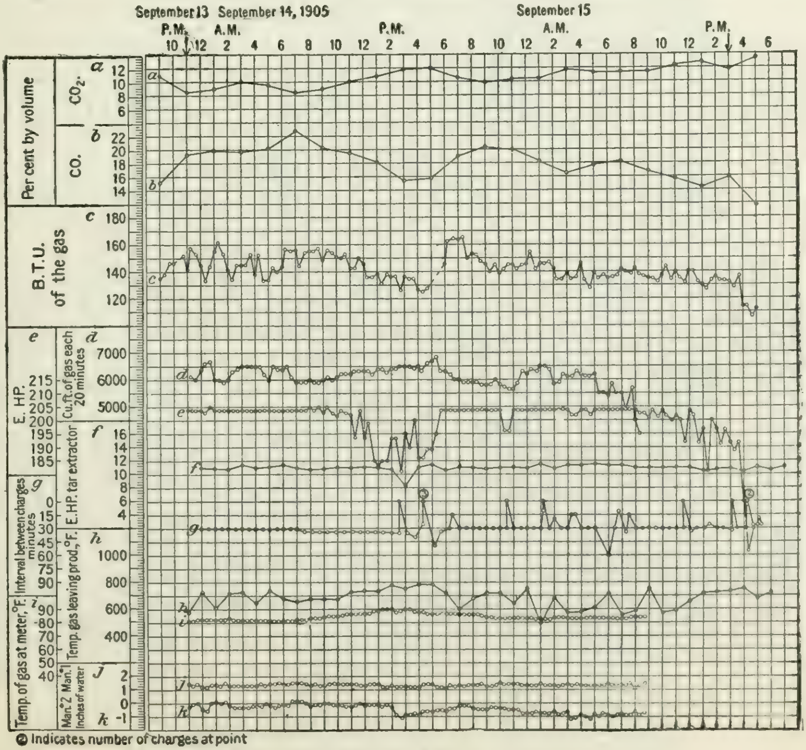
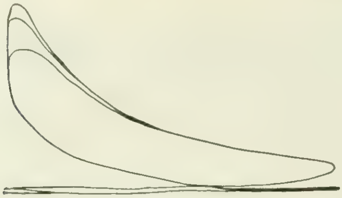


FIGURE 90.—Graphic log sheet, test No. 52, Indiana No. 9A coal.

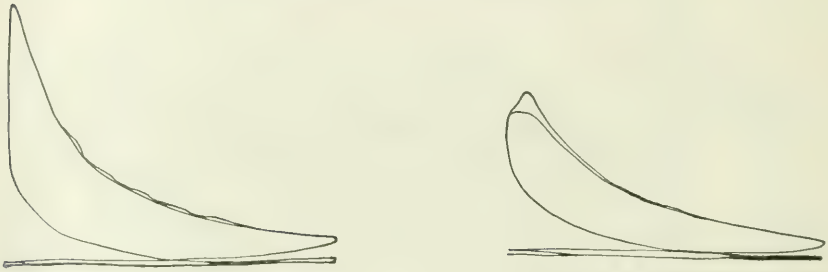


② Indicates number of charges at point

FIGURE 91.—Graphic log sheet, test No. 61, Indiana No. 11 coal.



Center cylinder. M. E. P., 62; Max., 208; Rel., 33; I. H. P., 98.2.



Right cylinder. M. E. P., 66; Max., 298; Rel., 25; I. H. P., 104.5.

Left cylinder. M. E. P., 54; Max., 188; Rel., 26; I. H. P., 85.5.

FIGURE 92.—Indicator cards, test No. 61, Indiana No. 11 coal. Scale of spring, 80; revolutions per minute, 201.0.

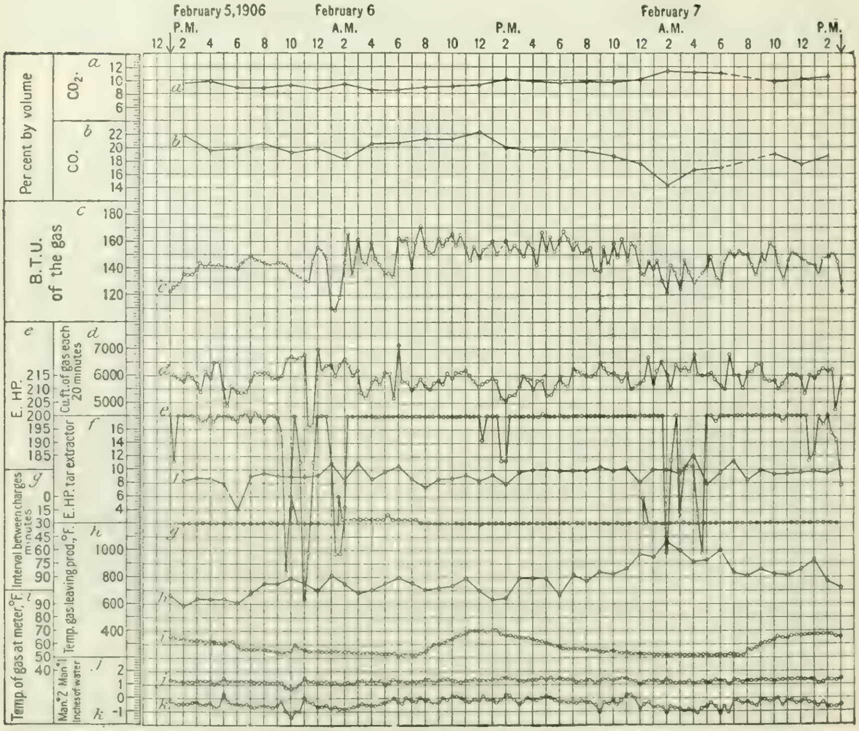


FIGURE 93.—Graphic log sheet, test No. 99, Indiana No. 12 coal.

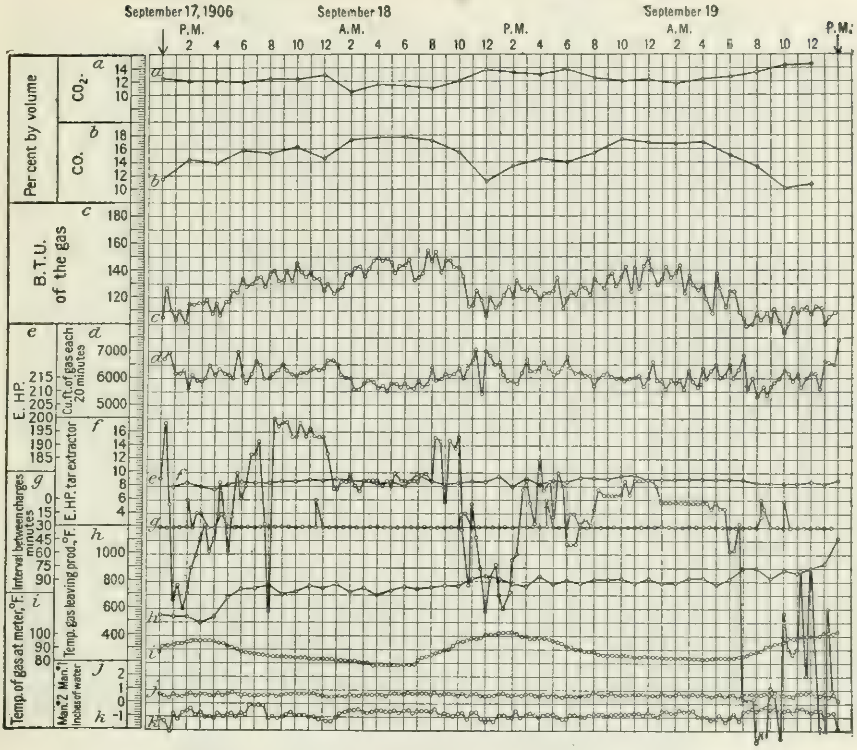


FIGURE 94.—Graphic log sheet, test No. 132, Indiana No. 13 coal.

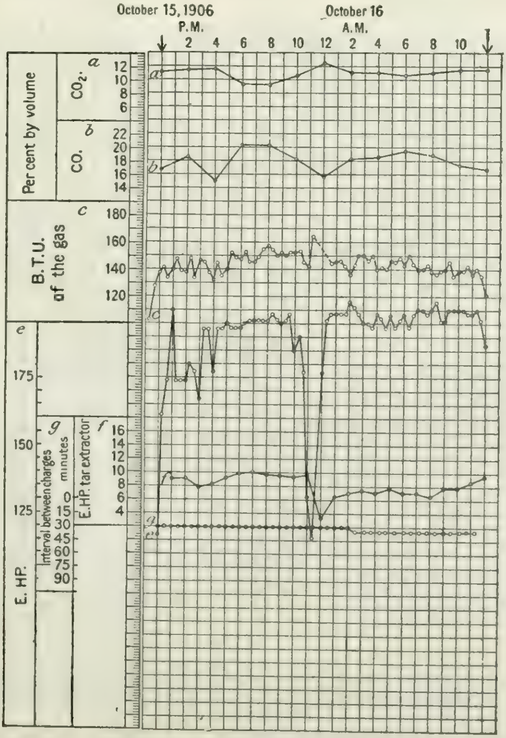


FIGURE 95.—Graphic log sheet, test No. 138, Indiana No. 13 coal.

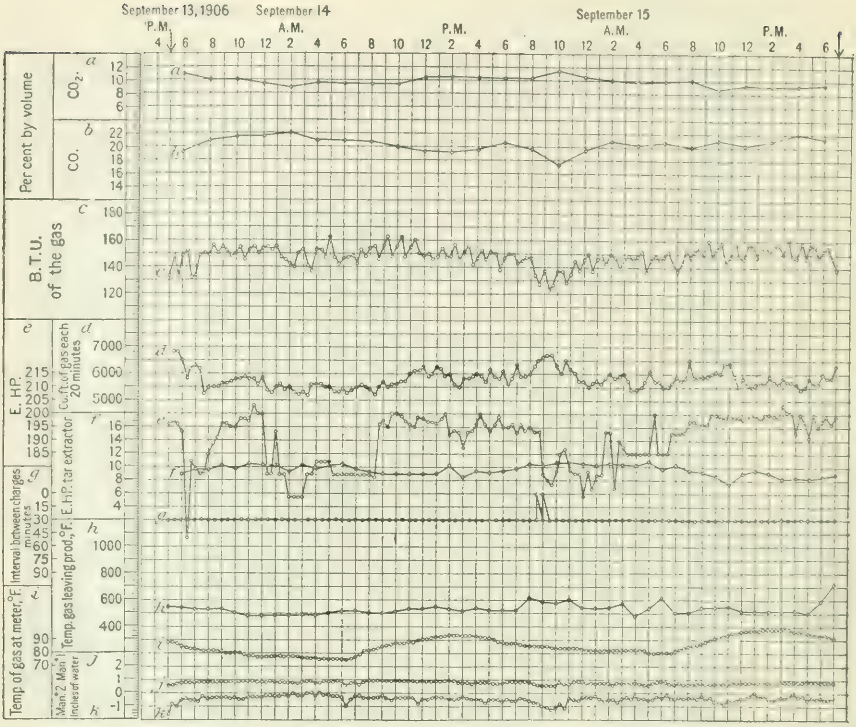


FIGURE 96.—Graphic log sheet, test No. 131, Indiana No. 14 coal.

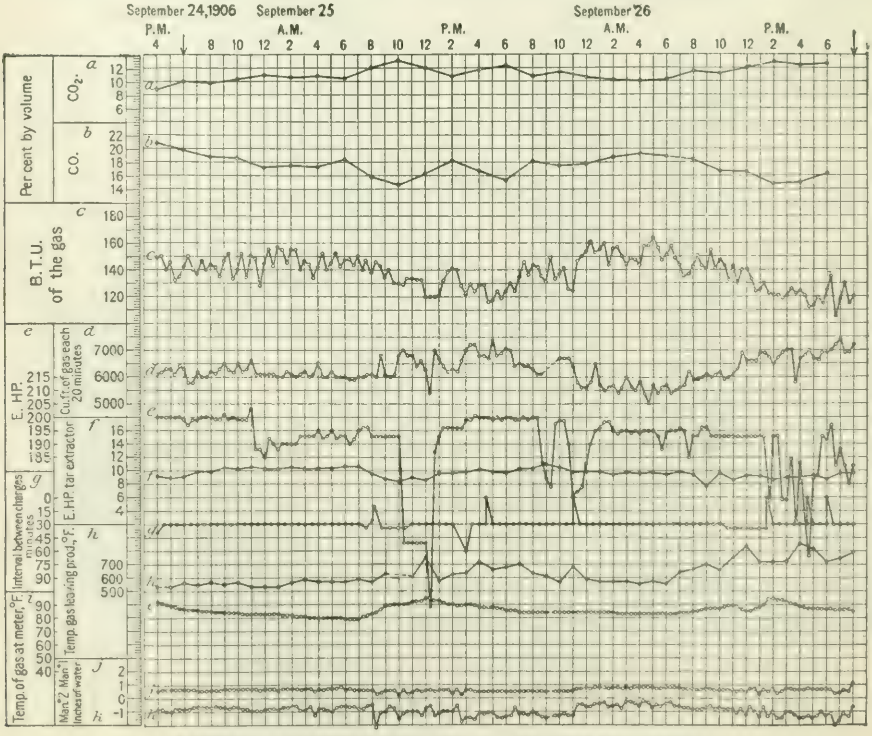


FIGURE 97.—Graphic log sheet, test No. 134, Indiana No. 15 coal.

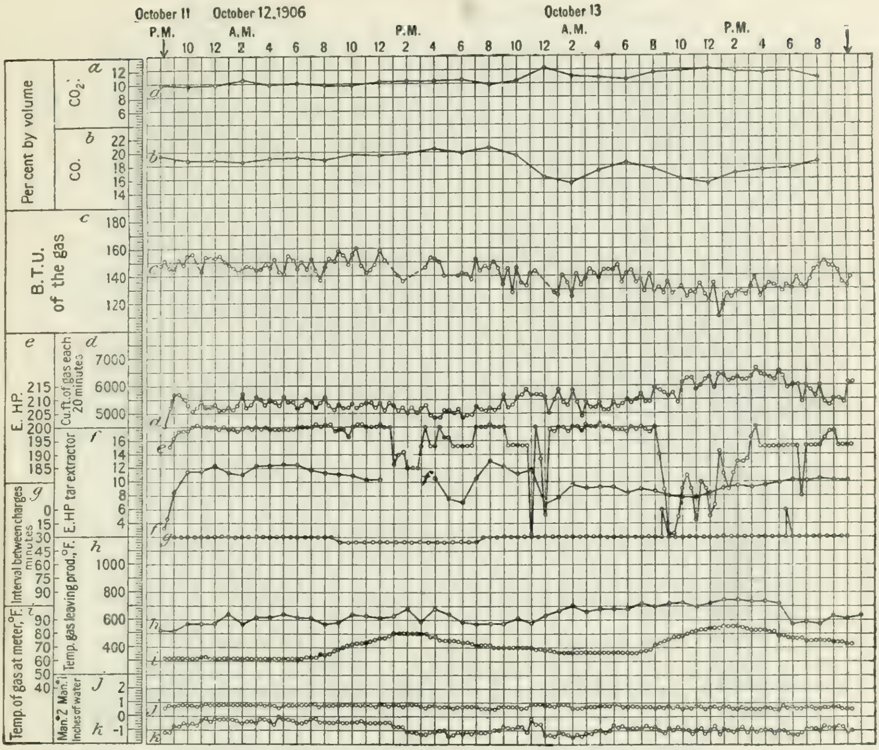


FIGURE 98.—Graphic log sheet, test No. 137, Indiana No. 15 coal.

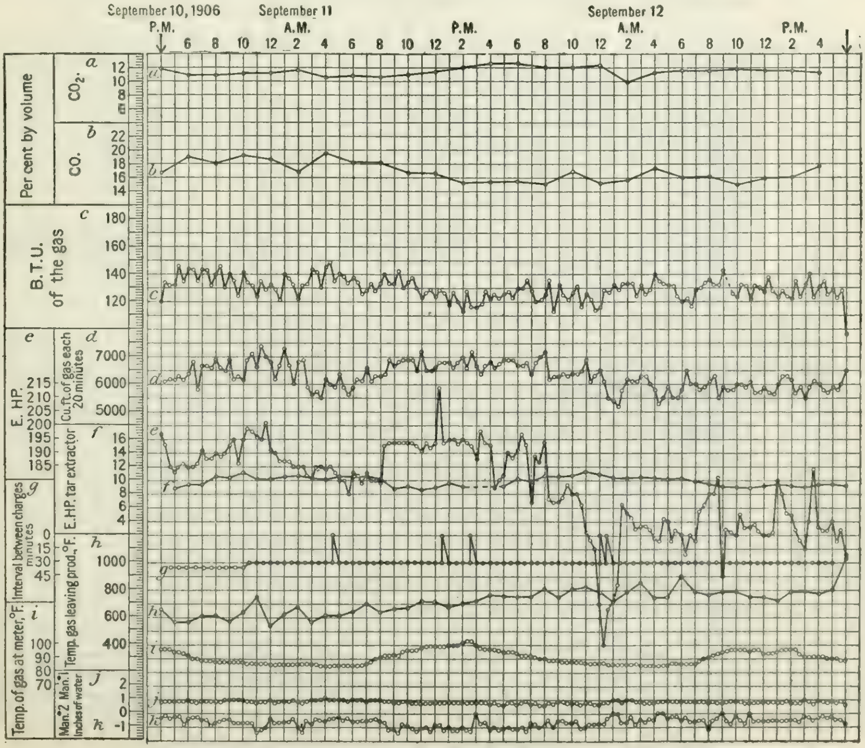


FIGURE 99.—Graphic log sheet, test No. 130, Indiana No. 16 coal.

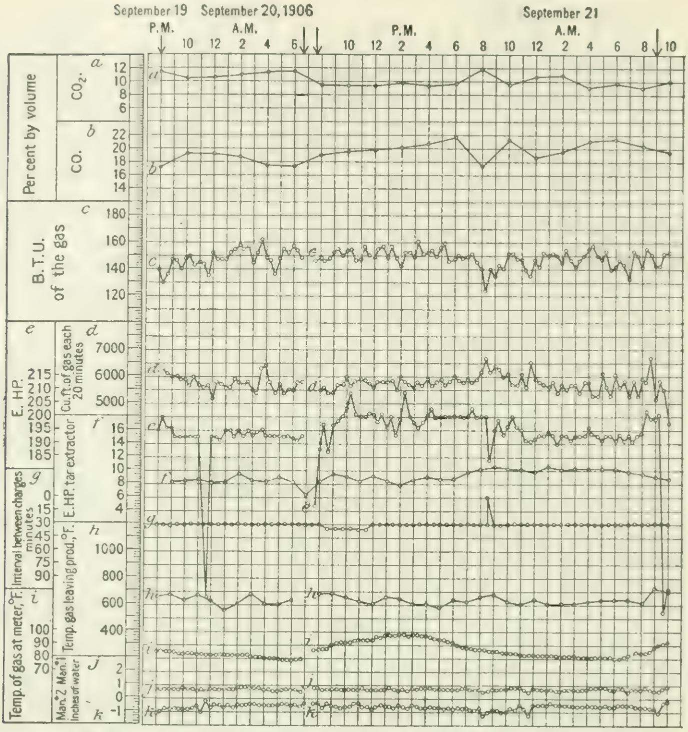


FIGURE 100.—Graphic log sheet, test No. 133, Indiana No. 18B coal.

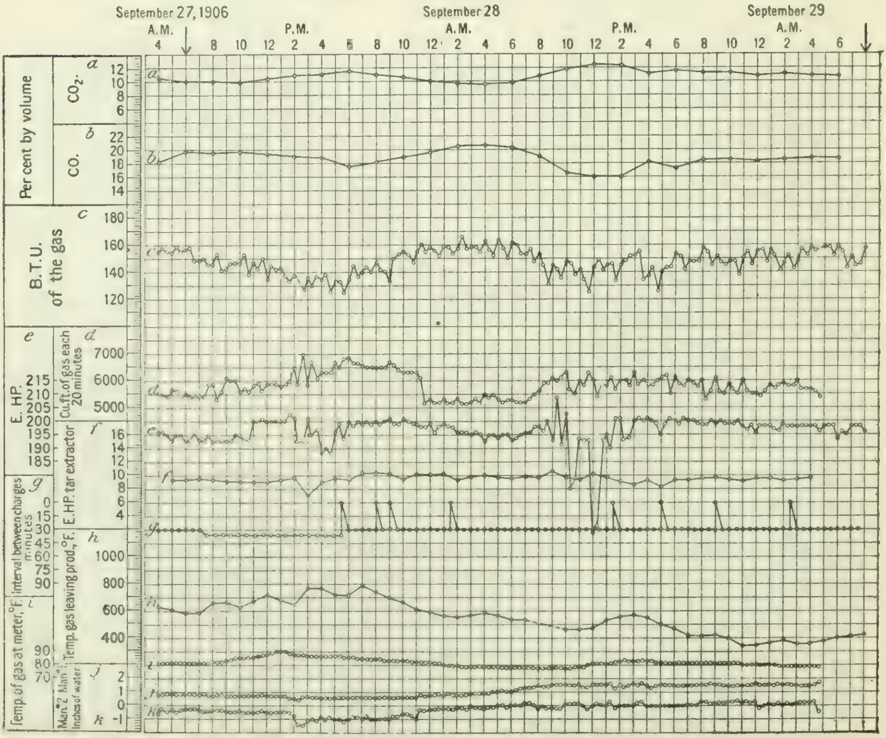
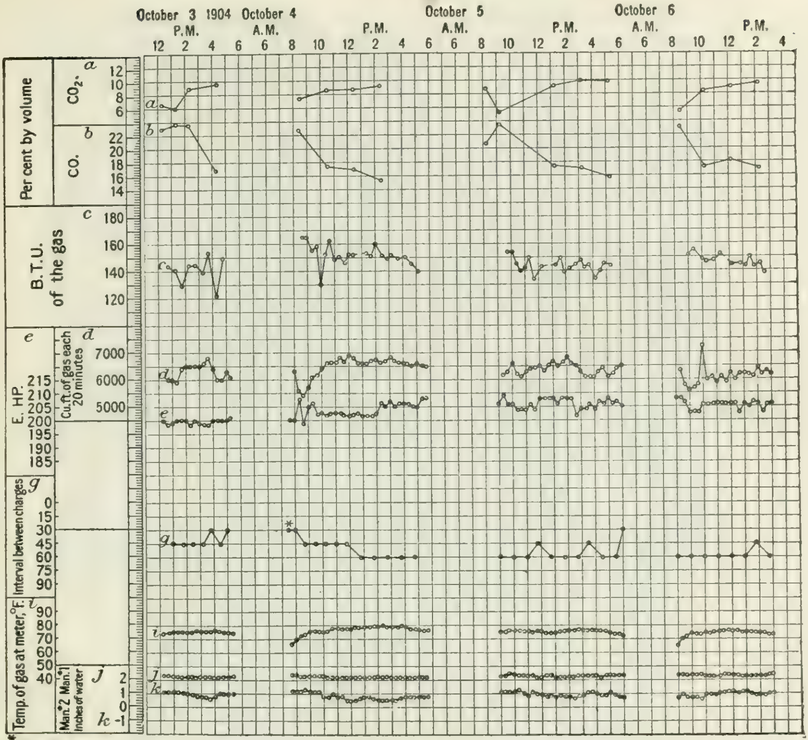


FIGURE 101.—Graphic log sheet, test No. 135, Indiana No. 18B coal.



*200 lb. charge

FIGURE 102.—Graphic log sheet, test No. 1, Indian Territory No. 1 coal.

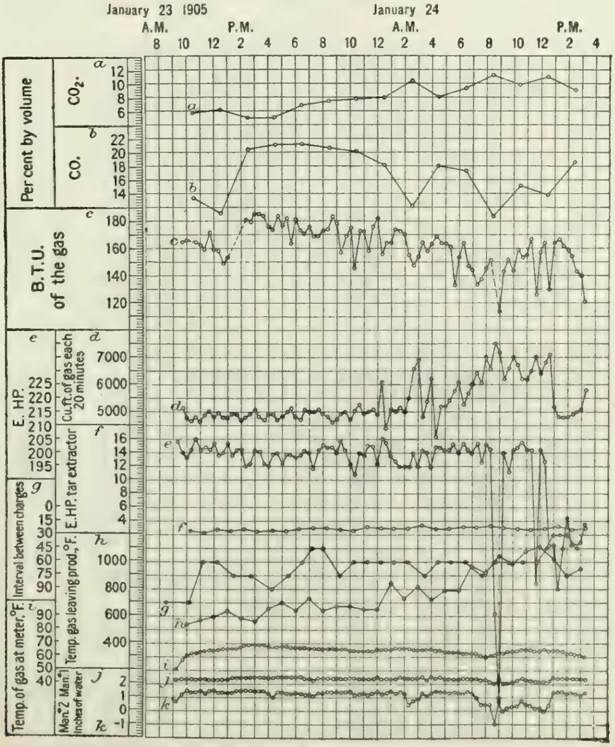


FIGURE 103.—Graphic log sheet, test No. 20, Indian Territory No. 4 coal.

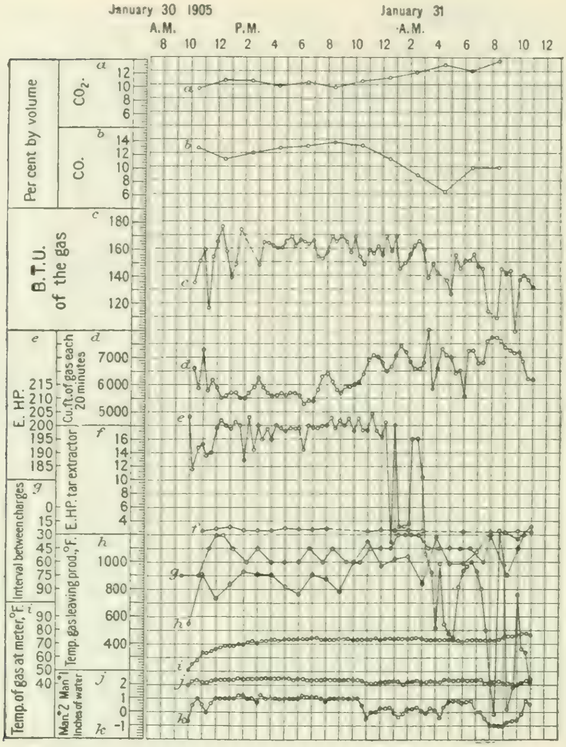


FIGURE 104.—Graphic log sheet, test No. 22, Iowa No. 2 coal.

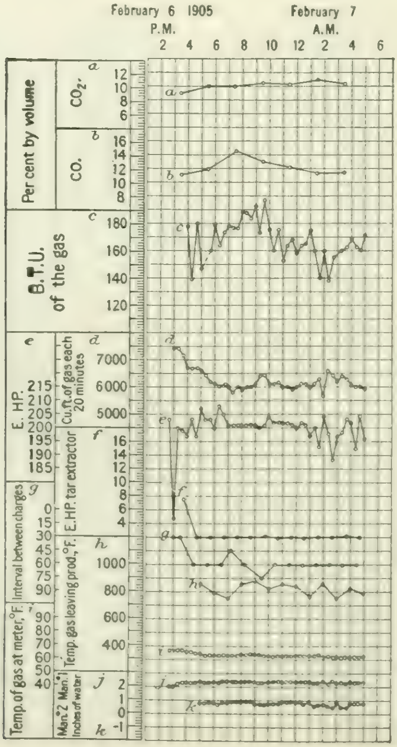


FIGURE 105.—Graphic log sheet, test No. 24, Kansas No. 5 coal.

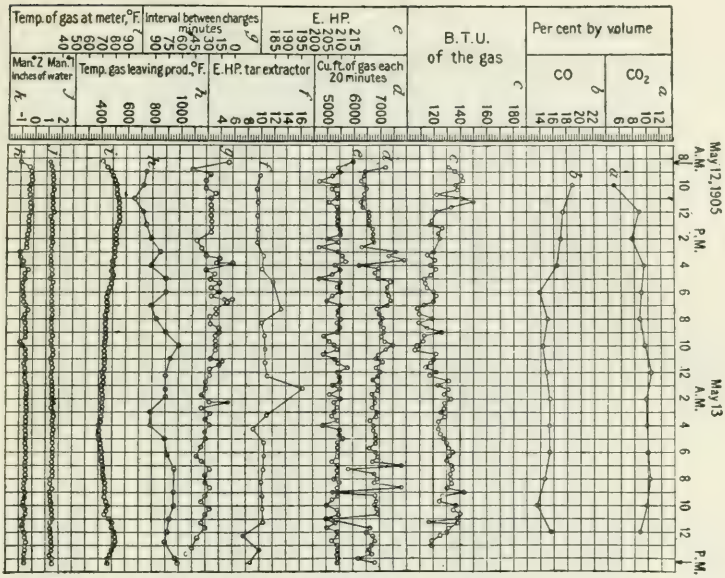
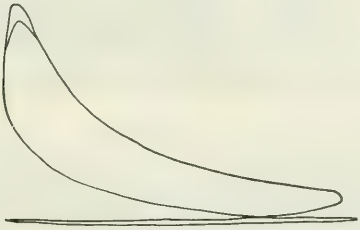
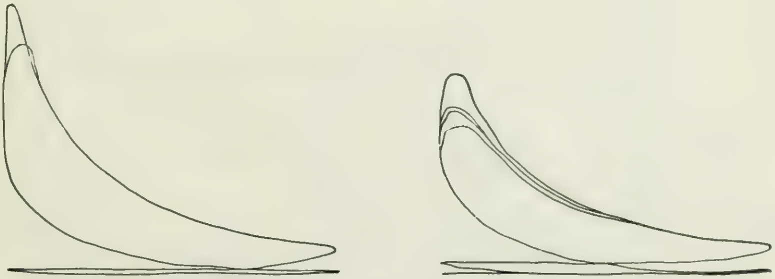


FIGURE 106.—Graphic log sheet, test No. 25, Kansas No. 5 coal.



Center cylinder, M. E. P., 66; Max., 248; Rel., 30;
I. H. P., 108.2.



Right cylinder, M. E. P., 70; Max., 274; Rel., 32;
I. H. P., 114.8.

Left cylinder, M. E. P., 48; Max., 214; Rel., 34;
I. H. P., 78.8.

FIGURE 107.—Indicator cards, test No. 25, Kansas No. 5 coal. Scale of spring, 80; revolutions per minute, 208.0.

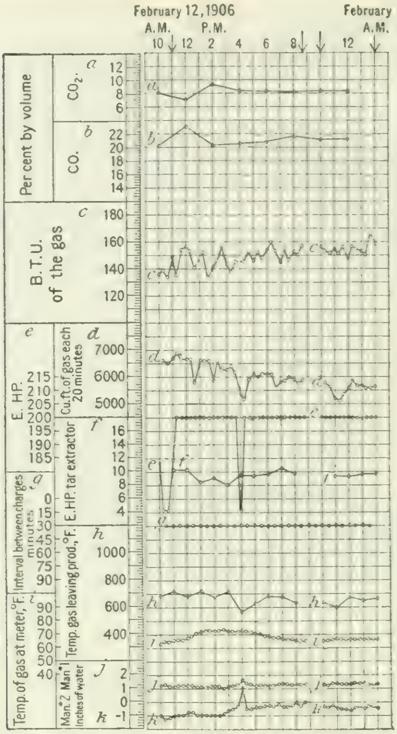


FIGURE 108.—Graphic log sheet, test No. 101, Kansas No. 6 coal.

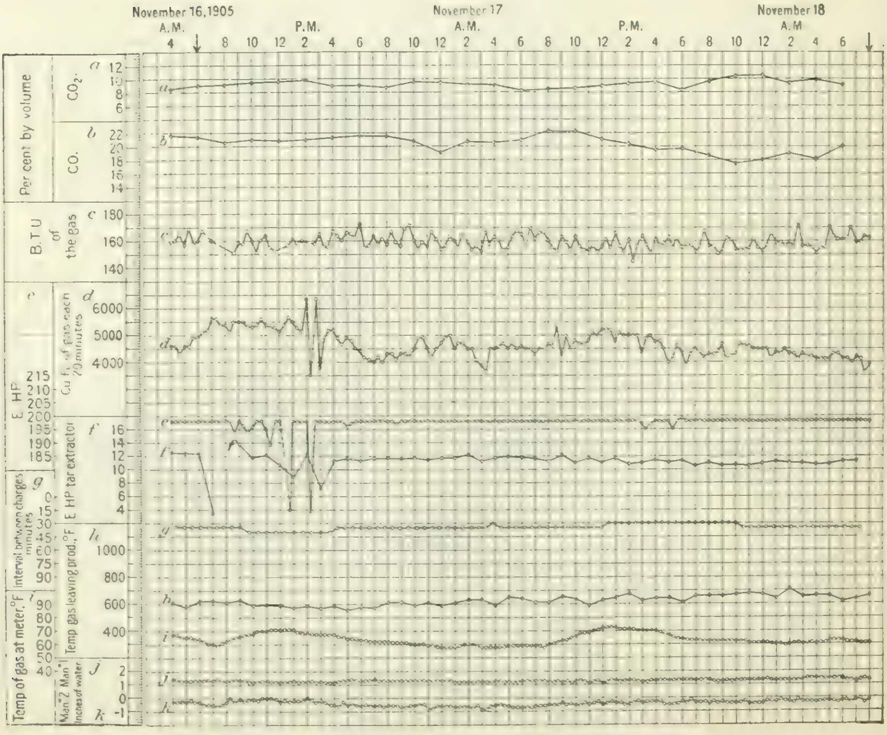


FIGURE 109.—Graphic log sheet, test No. 79, Kentucky No. 1B coal.

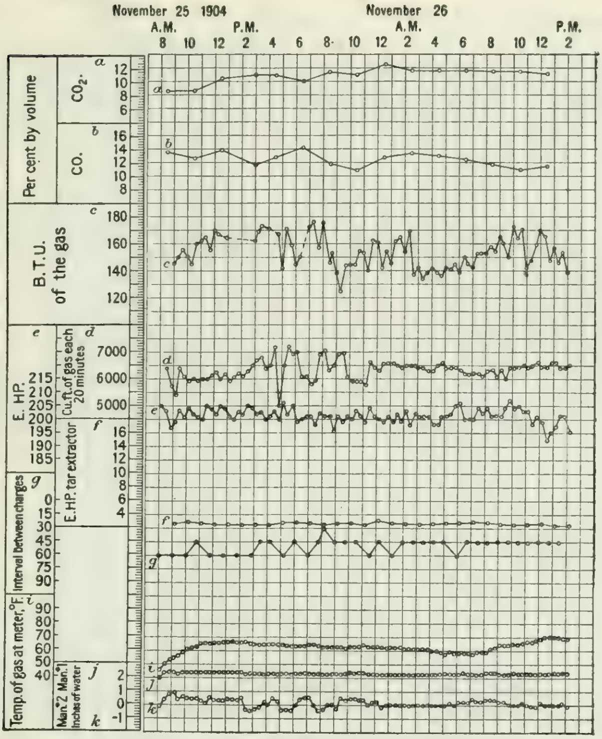


FIGURE 110.—Graphic log sheet, test No. 12, Kentucky No. 3 coal.

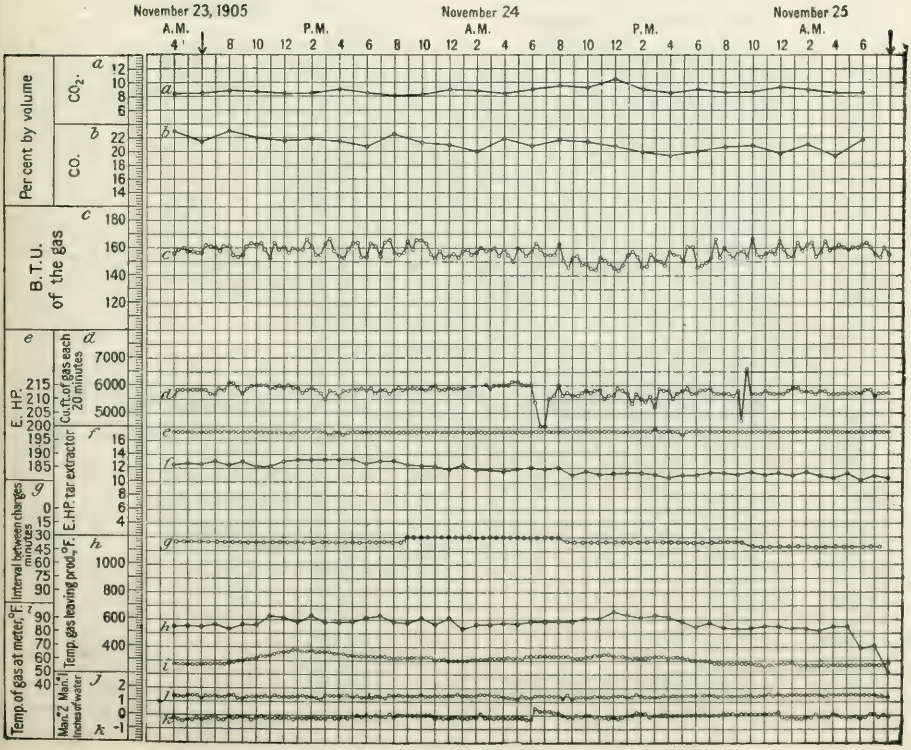


FIGURE 111.—Graphic log sheet, test No. 81, Kentucky No. 5 coal.

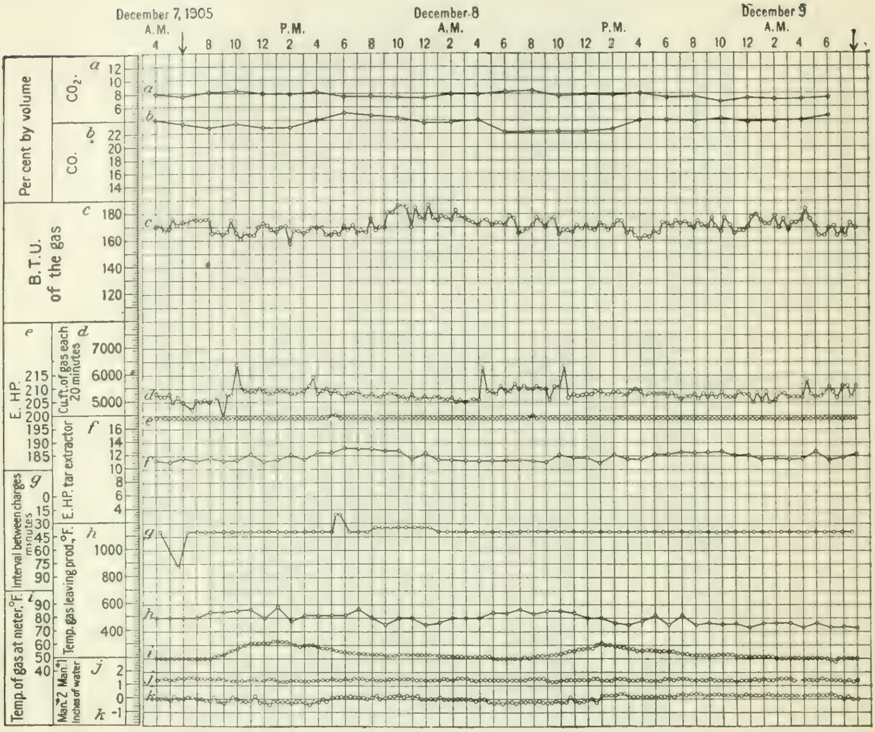


FIGURE 112.—Graphic log sheet, test No. 85, Kentucky No. 6 coal.

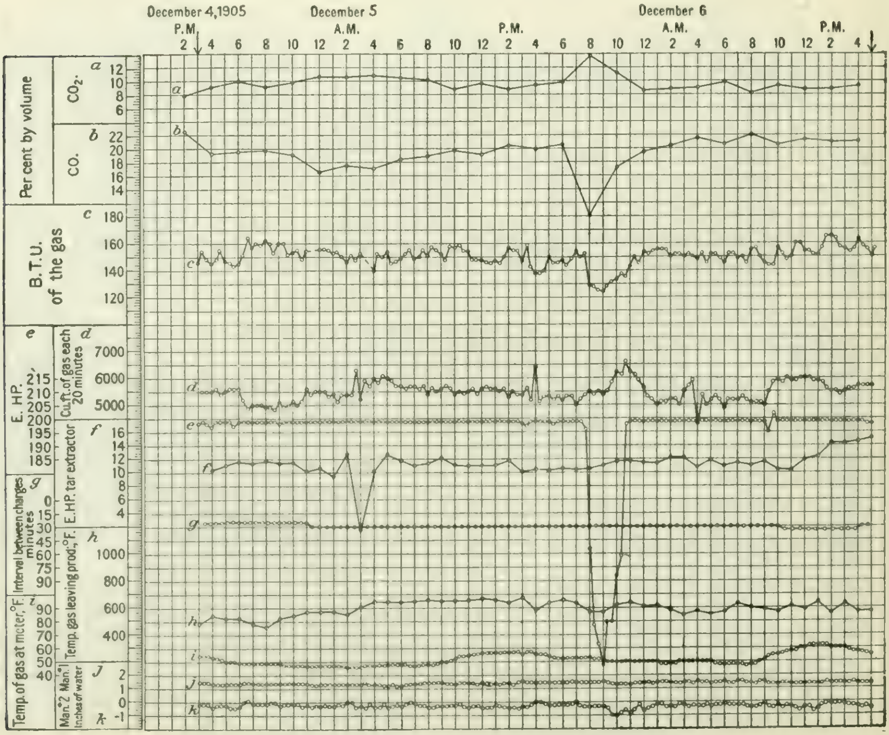
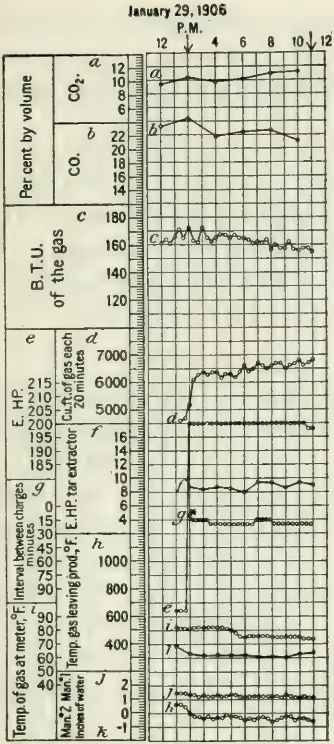


FIGURE 113.—Graphic log sheet, test No. 84, Kentucky No. 7 coal.



* 100 lb. charge at 2 P.M. 200 lbs 2.20 P.M. to 10.50

FIGURE 114.—Graphic log sheet, test No. 97, Massachusetts No. 1 coal.

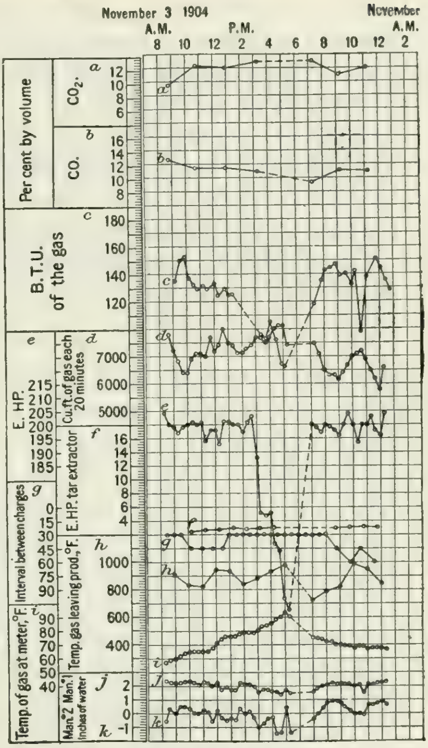


FIGURE 115.—Graphic log sheet, test Nos. 7A and 7B, Missouri No. 2 coal

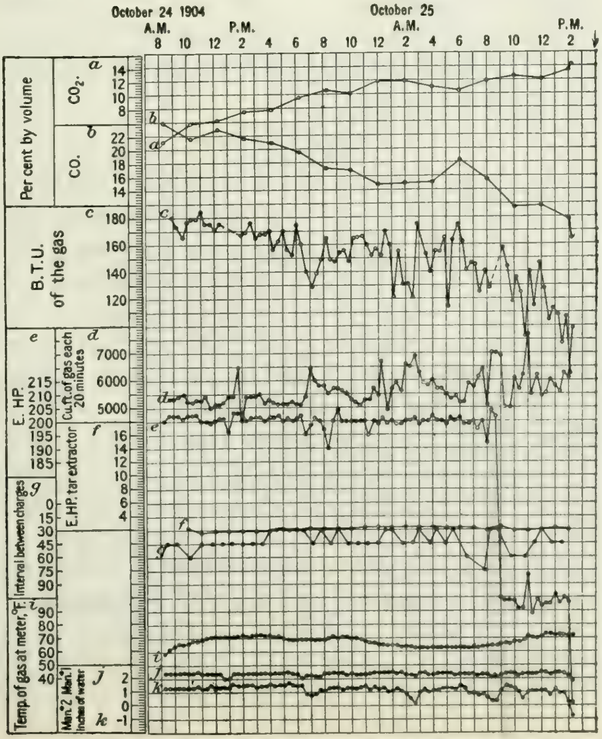


FIGURE 116.—Graphic log sheet, test Nos. 5A and 5B, Montana No. 1 coal.

in heat value. After the ash bed was properly ground down, however, the gas increased in heat value and the test continued without interruption. The quantity of coal available limited the test to 40 hours. Graphic log is given on page 171.

Montana No. 3, test 150.—Montana No. 3, a subbituminous coal, worked unusually well in the producer. The fuel bed was easily kept in good condition, and there was no indication of clinker. The heat value of the gas was high throughout the run, averaging 182 B. t. u. per cubic foot, and frequently the calorimeter indicated over 200 B. t. u. per cubic foot. Graphic log is given on page 171.

NEW MEXICO.

New Mexico No. 3A, test 121.—New Mexico No. 3A was similar in most respects to New Mexico No. 5. It was a little higher in ash, containing nearly 20 per cent. It was difficult to keep the fuel bed in good condition. The heat value of the gas, however, was fairly uniform and averaged 155 B. t. u. per cubic foot. The full 50-hour test was made, with full load. Graphic log is given on page 172.

New Mexico No. 4A, test 122.—New Mexico No. 4A was mostly slack and worked badly in the producer. Throughout the test the fuel bed required much attention and the gas fluctuated in heat value. The test lasted 50 hours, with about 95 per cent of full load. Graphic log is given on page 172.

New Mexico No. 5, test 120.—New Mexico No. 5 was a clean-appearing coal which was rather difficult to handle in the producer as considerable effort was required to keep the fuel bed in good condition. Nevertheless, the gas produced was of good quality and fairly uniform in heat value. The test lasted 45 hours, with approximately full load. Graphic log is given on page 173.

NORTH DAKOTA.

North Dakota No. 1B, test 68.—North Dakota No. 1B was a brown lignite similar to North Dakota No. 3, but with a little more volatile matter and less moisture. It gave some trouble, due to its tendency to clinker, but with proper care it makes a reliable producer-gas fuel. The gas was uniform in quality and had an average heat value of 161 B. t. u. per cubic foot. As there was no steaming test on this fuel, the apparent evaporation of North Dakota No. 3 was used in the calculations. Graphic log is given on page 173.

North Dakota No. 2, test 10.—North Dakota No. 2 was a brown lignite. It was an ideal producer fuel except for its tendency to clinker. It yielded a rich gas, which was of very uniform quality throughout the test. Fifty gallons of tar were extracted. This tar was yellow and sticky and not at all like that from bituminous coal. The fuel bed had to be kept deeper than with soft coal and had to be poked frequently to prevent the formation of clinker. After 30 hours'

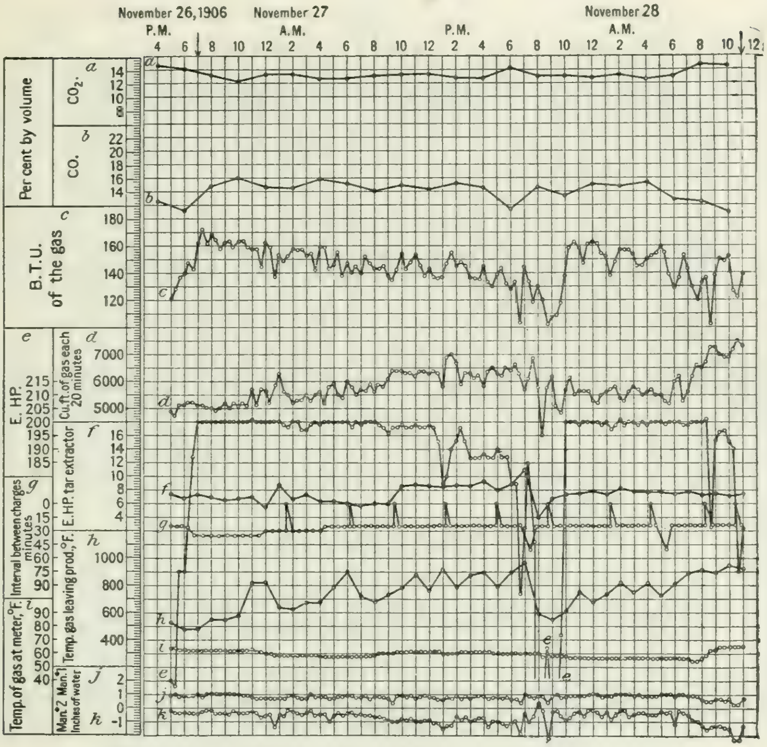


FIGURE 117.—Graphic log sheet, test No. 149, Montana No. 2 coal.

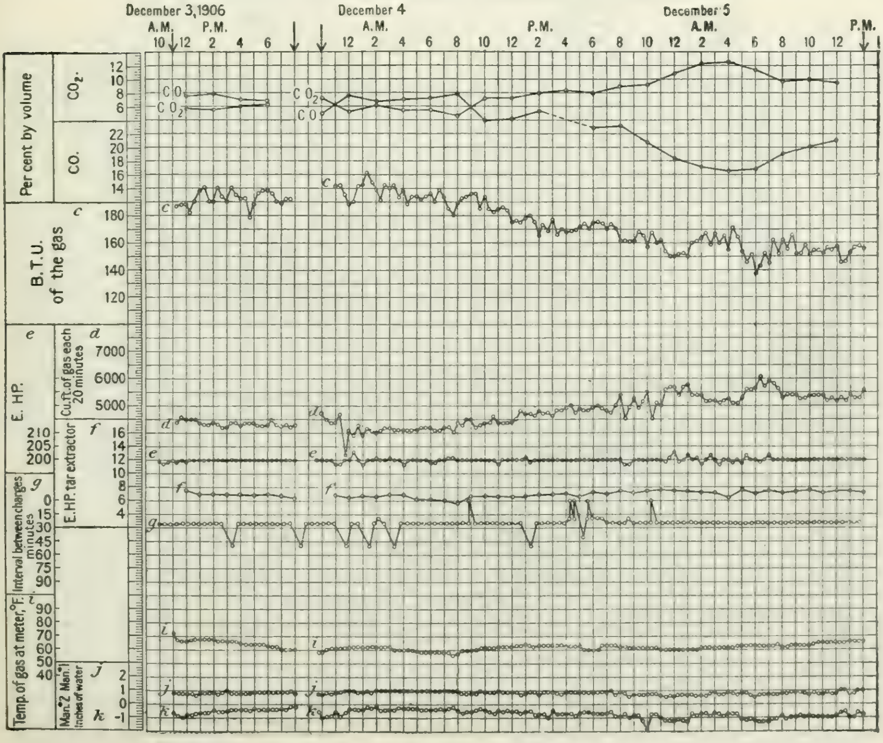


FIGURE 118.—Graphic log sheet, test No. 150, Montana No. 3 coal.

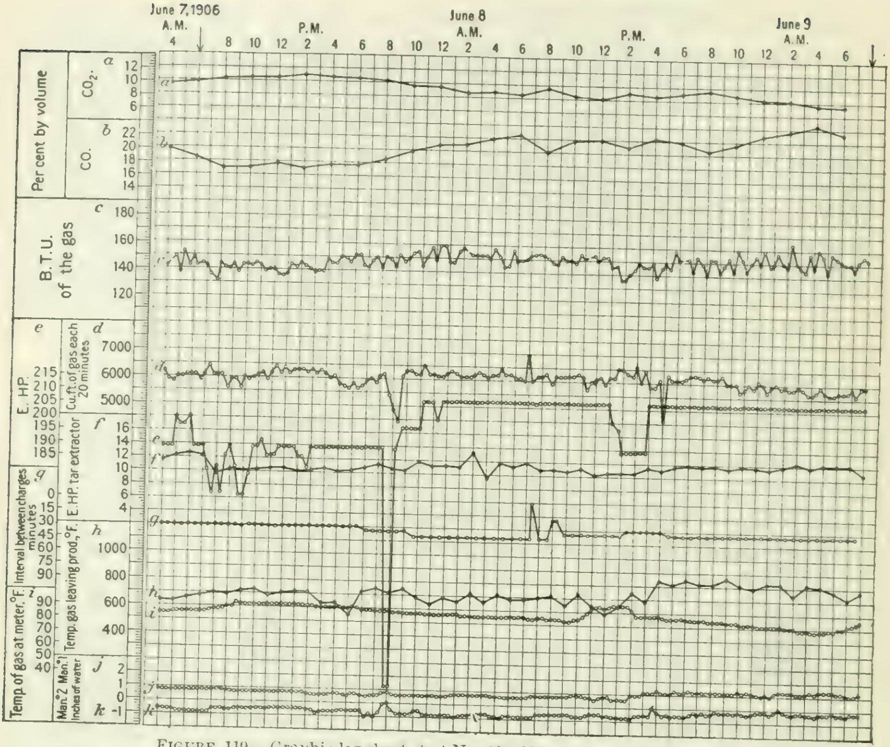
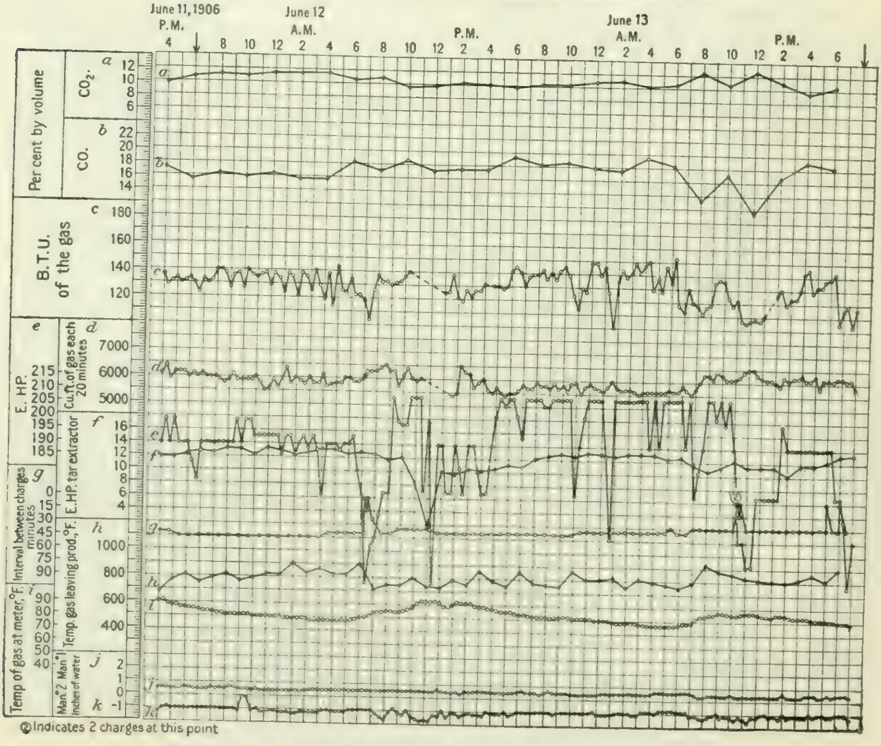


FIGURE 119.—Graphic log sheet, test No. 121, New Mexico No. 3A coal.



② Indicates 2 charges at this point

FIGURE 120.—Graphic log sheet, test No. 122, New Mexico No. 4A coal.

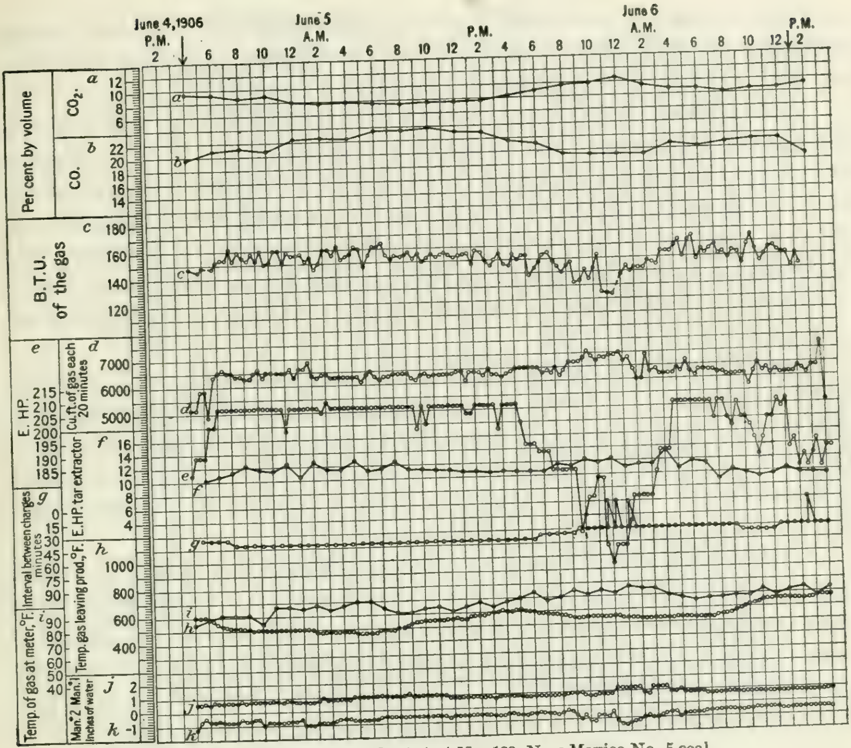
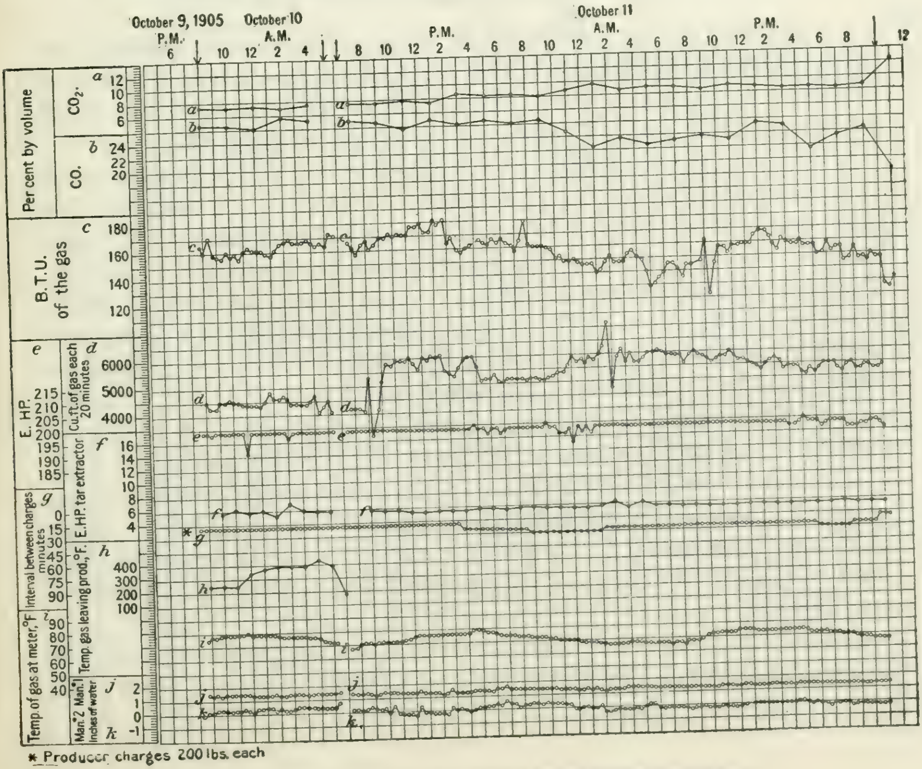


FIGURE 121.—Graphic log sheet, test No. 120, New Mexico No. 5 coal.



* Producer charges 200 lbs. each

FIGURE 122.—Graphic log sheet, test No. 68, North Dakota No. 1B coal.

continuous run the fuel bed was in good condition. The heat value of the gas (188.5 B. t. u. per cubic foot) was higher than that from any other fuel tested. Graphic log is given on page 175.

North Dakota No. 2B, test 72.—North Dakota No. 2B was a brown lignite from the same mine as the fuel used in test No. 10. No trouble was experienced in carrying full load, and the fuel bed was easily kept in good condition. The gas had an average heat value of 164 B. t. u. per cubic foot and was of uniform quality. As there was no steaming test on this fuel, the apparent evaporation of North Dakota No. 3 was used in the calculations. Graphic log is given on page 175.

North Dakota No. 2B, test 152.—This fuel, a brown lignite of rather light weight, worked well in the producer. The gas was of uniform quality and had an average heat value of 145 B. t. u. per cubic foot. Owing to the lack of fuel the test lasted only 12 hours. The apparent evaporation of North Dakota No. 3 was used in the calculations. Graphic log is given on page 176.

North Dakota No. 3, test 67.—North Dakota No. 3 was a brown lignite containing over 35 per cent of moisture. It made a gas with an average heat value of 159 B. t. u. per cubic foot. No difficulty was experienced in burning about 16 pounds of fuel an hour per square foot of fuel-bed area. The standard 50-hour test was run with ease, carrying full load. Graphic log is given on page 176.

OHIO.

Ohio No. 3, test 64.—Ohio No. 3, a run-off-mine coal, worked satisfactorily in the producer. The gas had an average heat value of 156 B. t. u. per cubic foot. The standard 50-hour test was easily made, with full load. Graphic log is given on page 177.

Ohio No. 4, test 60.—Due to the clogging of the economizer tubes with tar and soot, it was impossible to complete the standard 50-hour test. This clogging is not necessarily chargeable to the fuel used for the test. The tar and soot had been gradually accumulating in the tubes, but not in sufficient quantities to interfere with the working of the plant. The results obtained during the shortened test were satisfactory and the coal was shown to be a good producer fuel. The gas, which had an average heat value of 149 B. t. u. per cubic foot, was not as uniform in quality as in some cases, but on the whole was satisfactory. Graphic log is given on page 178.

Ohio No. 5, test 58.—Ohio No. 5, a lump coal, easily handled in the producer, may be considered a good producer fuel. The heat value of the gas averaged 152 B. t. u. per cubic foot. The standard 50-hour test was run with ease, carrying full load. Graphic log is given on page 179.

Ohio No. 6, test 76.—Ohio No. 6 was a good producer coal. It worked well in run-of-mine form, and supplied a gas of fairly uni-

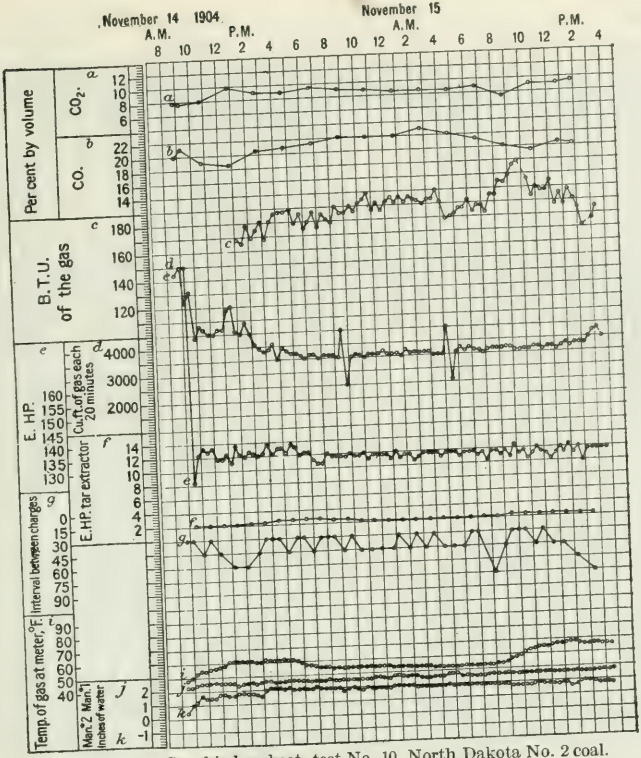


FIGURE 123.—Graphic log sheet, test No. 10, North Dakota No. 2 coal.

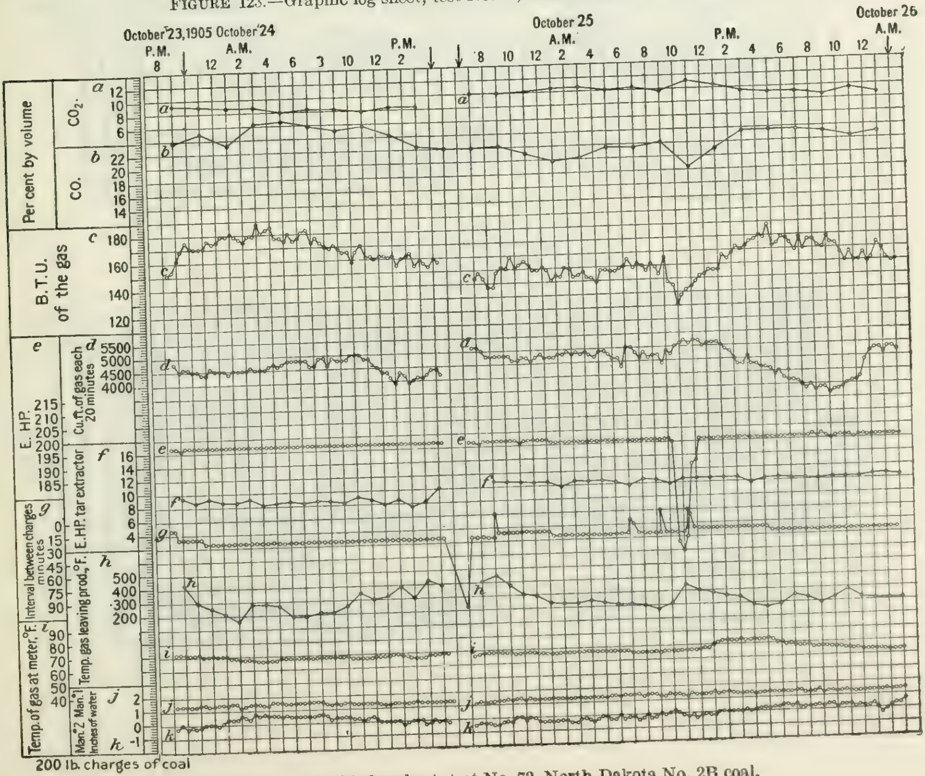
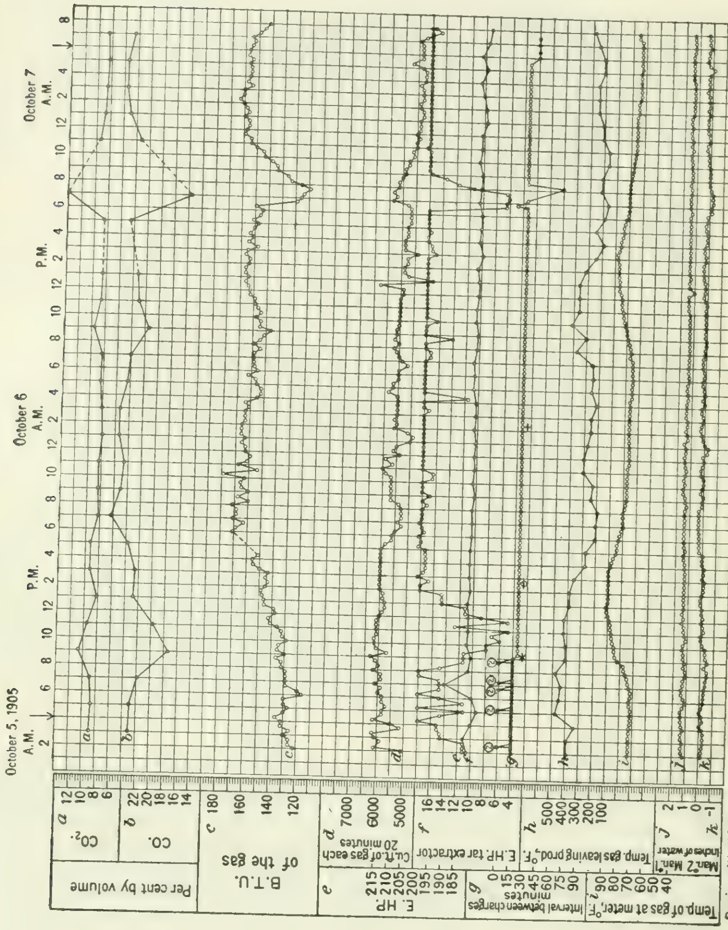


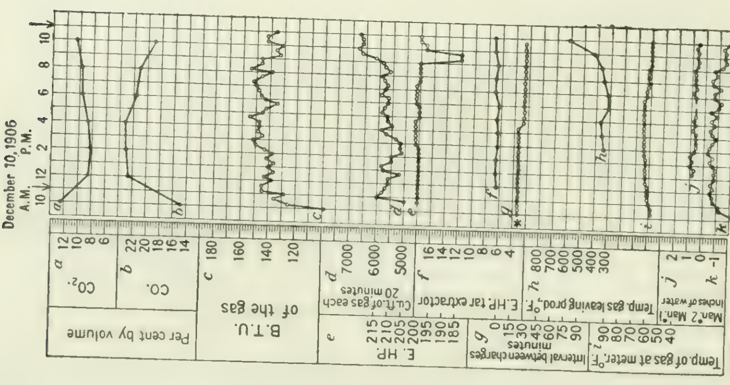
FIGURE 124.—Graphic log sheet, test No. 72, North Dakota No. 2B coal.



Begin with 100 lb. charges, * 9.20 P.M., 200 lbs., ⇾ 3 P.M., 225 lbs., + 2.20 A.M., 220 lbs.

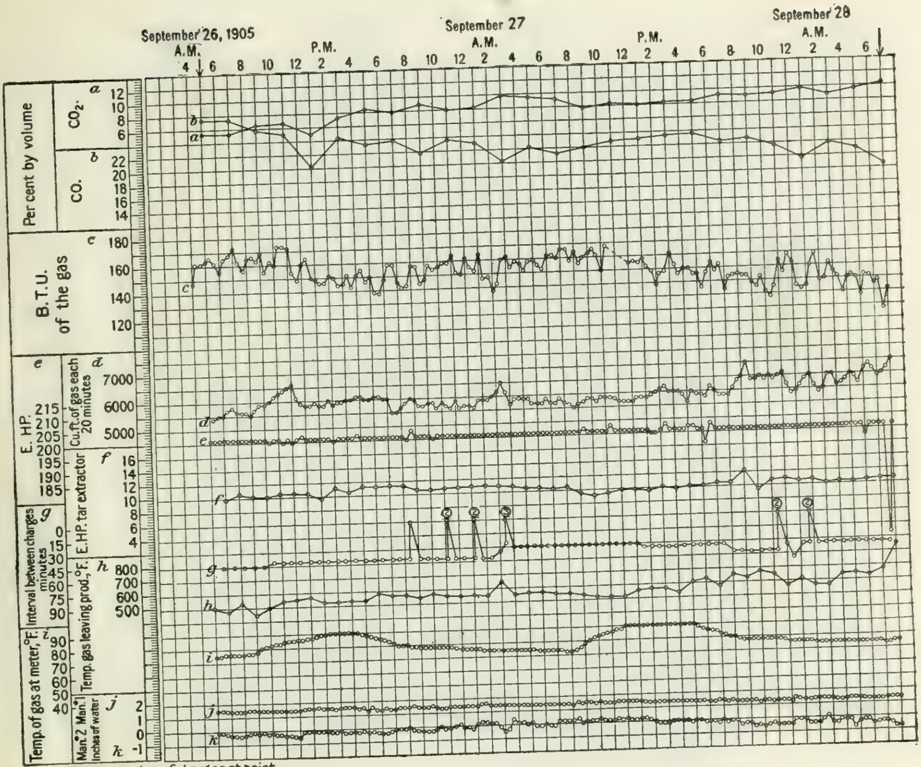
② Indicates 2 charges at this point

FIGURE 126.—Graphic log sheet, test No. 67, North Dakota No. 3 coal.



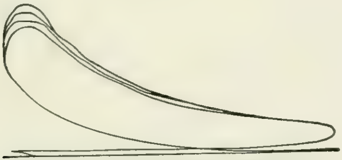
* Charges 200 lbs. each throughout test

FIGURE 125.—Graphic log sheet, test No. 152, North Dakota No. 2B coal.

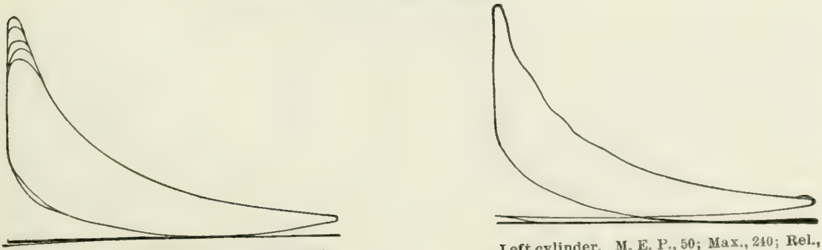


② Indicates number of charges at point

FIGURE 127.—Graphic log sheet, test No. 64, Ohio No. 3 coal.



Center cylinder. M. E. P., 52; Max., 179; Rel., 34; I. H. P., 84.5.



Right cylinder. M. E. P., 62; Max., 240; Rel., 32; I. H. P., 100.8.

Left cylinder. M. E. P., 50; Max., 240; Rel., 32; I. H. P., 81.3.

FIGURE 128.—Indicator cards, test No. 64, Ohio No. 3 coal. Scale of spring, 80; revolutions per minute, 206.5.

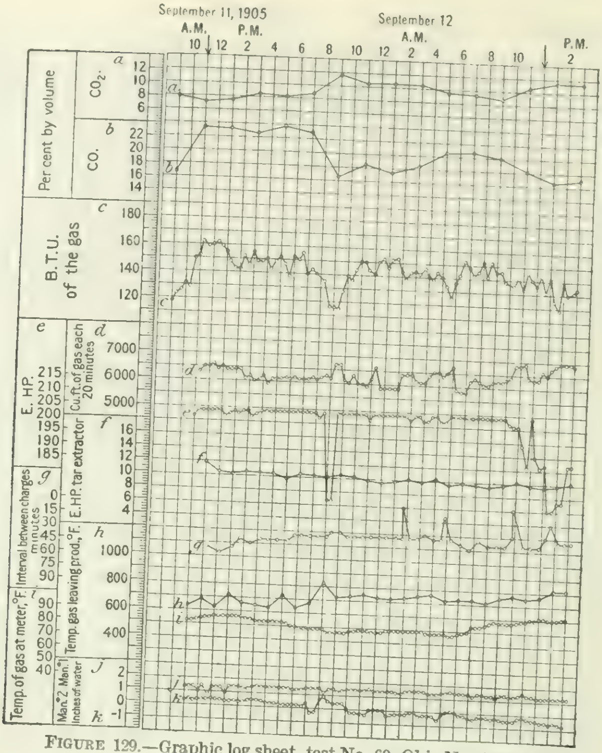
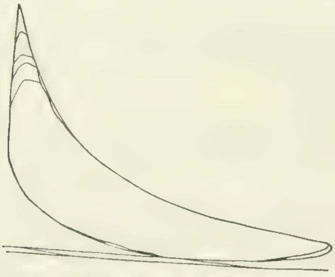
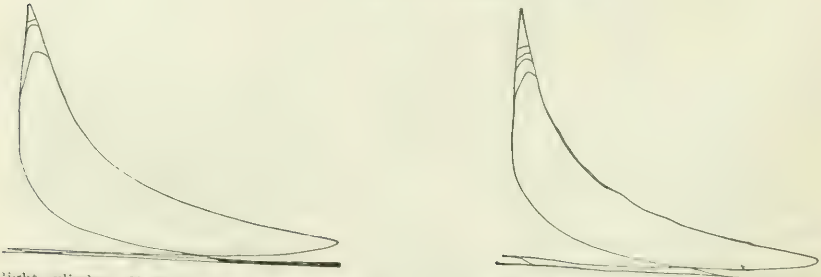


FIGURE 129.—Graphic log sheet, test No. 60, Ohio No. 4 coal.



Center cylinder. M. E. P., 66; Max., 260; Rel., 44; I. H. P., 105.2.



Right cylinder. M. E. P., 64; Max., 270; Rel., 36; I. H. P., 102.0.

Left cylinder. M. E. P., 62; Max., 290; Rel., 36 I. H. P., 99.0.

FIGURE 130.—Indicator cards, test No. 60, Ohio No. 4 coal. Scale of spring, 80; revolutions per minute, 202.4.

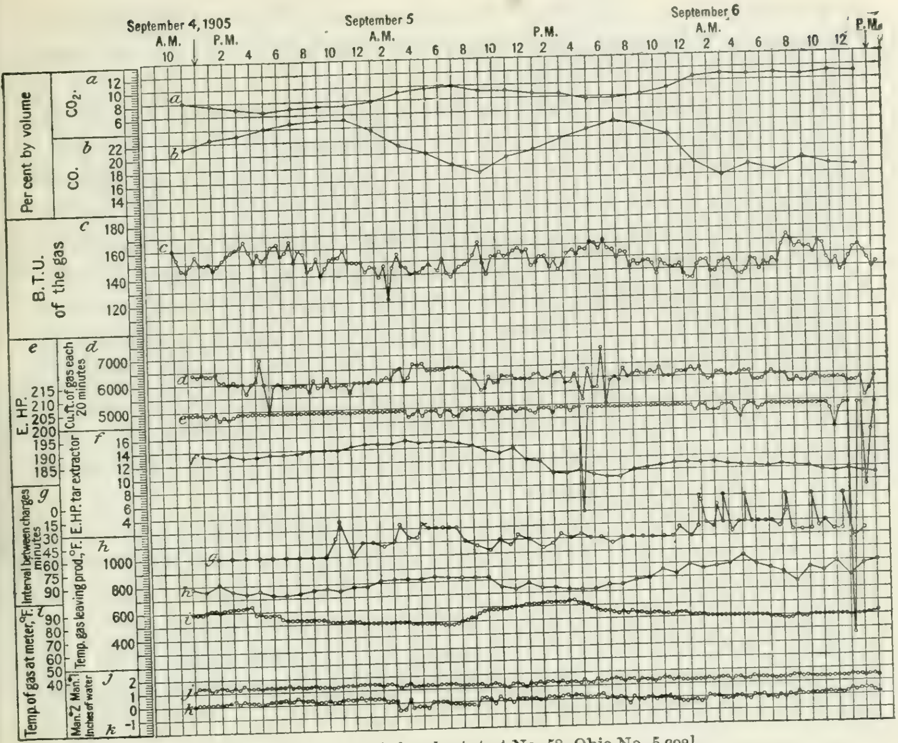
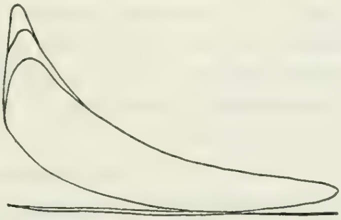
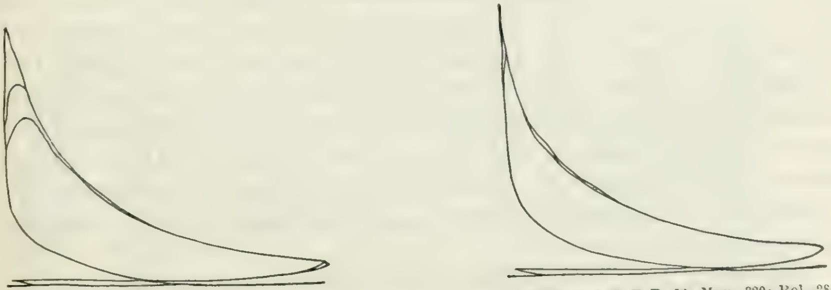


FIGURE 131.—Graphic log sheet, test No. 58, Ohio No. 5 coal.



Center cylinder. M. E. P., 70; Max., 210; Rel., 30; I. H. P., 112.0.



Right cylinder. M. E. P., 62; Max., 270; Rel., 27; I. H. P., 99.2.

Left cylinder, M. E. P., 52; Max., 320; Rel., 28; I. H. P., 83.2.

FIGURE 132.—Indicator cards, test No. 58, Ohio No. 5 coal. Scale of spring, 80; revolutions per minute, 203.0.

form quality with an average heat value of 163 B. t. u. per cubic foot. The standard 50-hour test was easily completed, with full load. Graphic log is given on page 181.

Ohio No. 7, test 87.—This test was stopped at the end of 41 hours by the clogging with tar of a new water-seal valve. The value of the test is somewhat impaired by this occurrence, inasmuch as the efficiency shown is undoubtedly too low for this grade of fuel; but the test is presented for what it is worth. Graphic log is given on page 181.

Ohio No. 8, test 83.—Ohio No. 8 was an entirely satisfactory producer fuel. The blowing out of a plug in one of the exhaust valves caused a shutdown of 3 hours. Preheated air was used during the entire test. The fuel was fed at the rate of 150 pounds every 30 minutes, the bed rising gradually and consistently. A satisfactory gas with an average heat value of 170 B. t. u. per cubic foot was generated, and the standard 50-hour test, on full load, was easily made. Graphic log is given on page 182.

Ohio No. 9A, test 73.—Ohio No. 9A was a satisfactory producer fuel. No trouble was experienced in making gas with an average heat value of 155 B. t. u. per cubic foot. The tendency of the fuel bed to shrink away from the lining of the producer necessitated close watching, but the standard 50-hour test was easily run, with full load. As there was no boiler test on this coal the apparent evaporation of Ohio No. 9 was used in the calculations. Graphic log is given on page 182.

Ohio No. 10, test 142.—Ohio No. 10 was a clean, bright coal, with comparatively little slack. It worked remarkably well in the producer and gave excellent results. The heat value of the gas was fairly uniform and averaged 166 B. t. u. per cubic foot. A steady full load was easily maintained throughout the test of 50 hours. Graphic log is given on page 183.

Ohio No. 11, test 145.—Ohio No. 11 coal was delivered to the producer crushed to about egg size, but containing much fine coal. It worked well in the producer, showing no tendency to clinker. The gas was of uniform quality and had an average heat value of 165 B. t. u. per cubic foot. A steady full load was easily maintained throughout the run of 50 hours. Graphic log is given on page 183.

Ohio No. 12, test 146.—Ohio No. 12 coal worked well in the producer. The gas was exceptionally uniform in composition and had an average heat value of 165 B. t. u. per cubic foot. After 34 hours the test was stopped on account of soot clogging the gas flues in the economizer. A steady full load was carried during the run. Graphic log is given on page 185.

Ohio No. 12, test 147.—This coal gave good results. The gas was of uniform composition and had an average heat value of 165 B. t. u. per cubic foot. After running 36 hours the tar extractor was put out

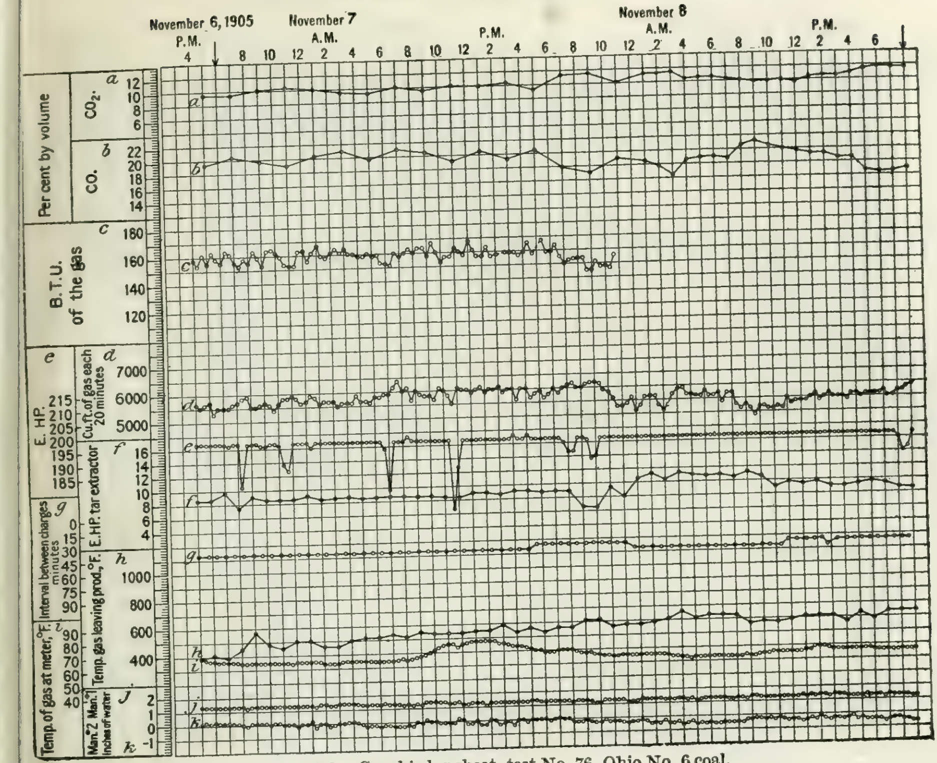


FIGURE 133.—Graphic log sheet, test No. 76, Ohio No. 6 coal.

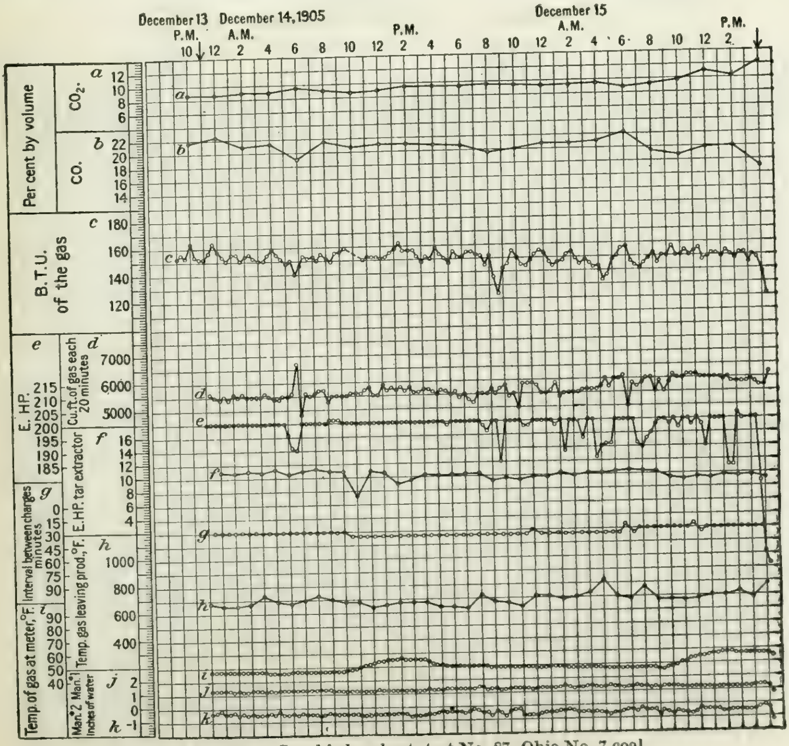
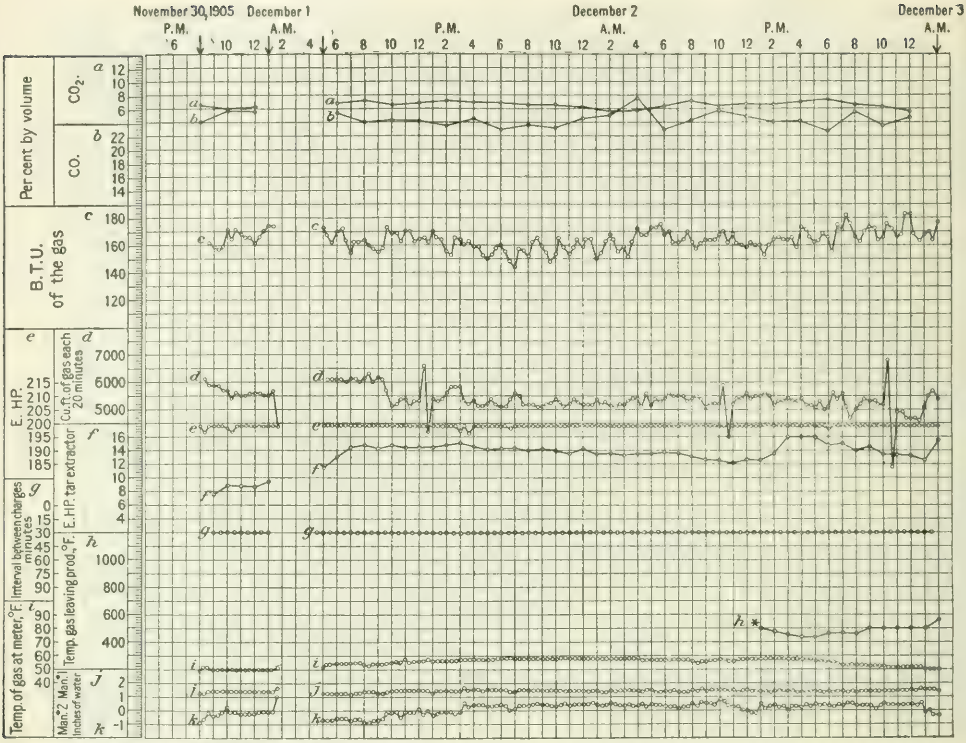


FIGURE 134.—Graphic log sheet, test No. 87, Ohio No. 7 coal.



* Temperature not taken until 1 P.M. December 2

FIGURE 135.—Graphic log sheet, test No. 83, Ohio No. 8 coal.

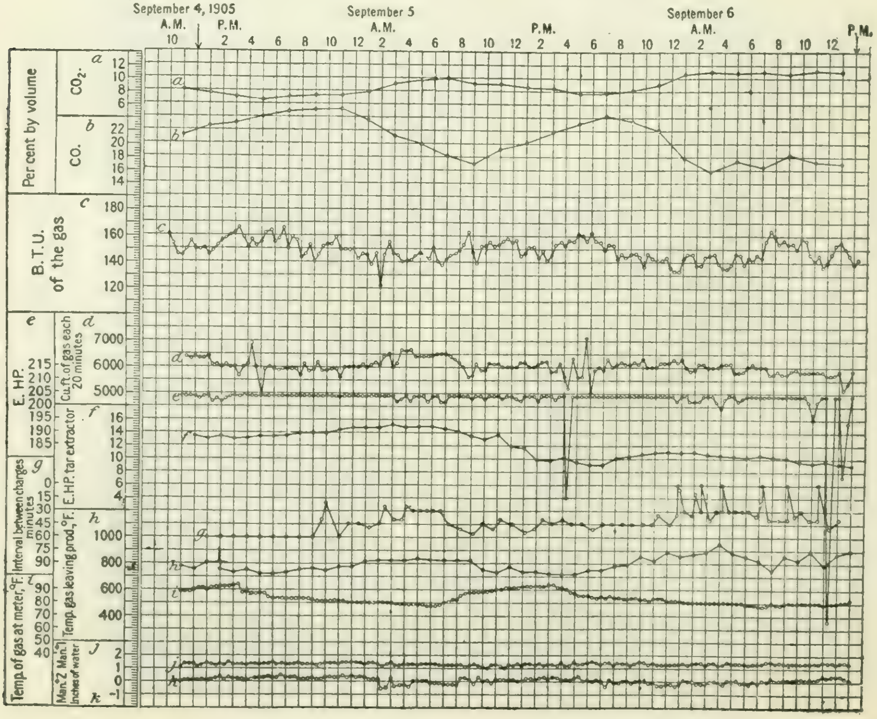


FIGURE 136.—Graphic log sheet, test No. 73, Ohio No. 9A coal.

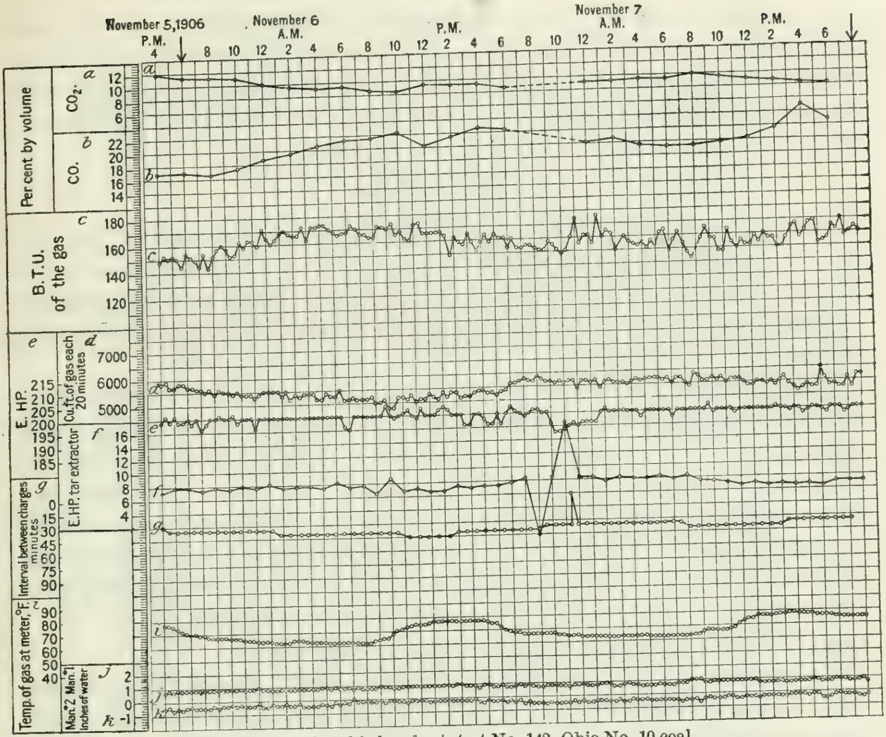


FIGURE 137.—Graphic log sheet, test No. 142, Ohio No. 10 coal.

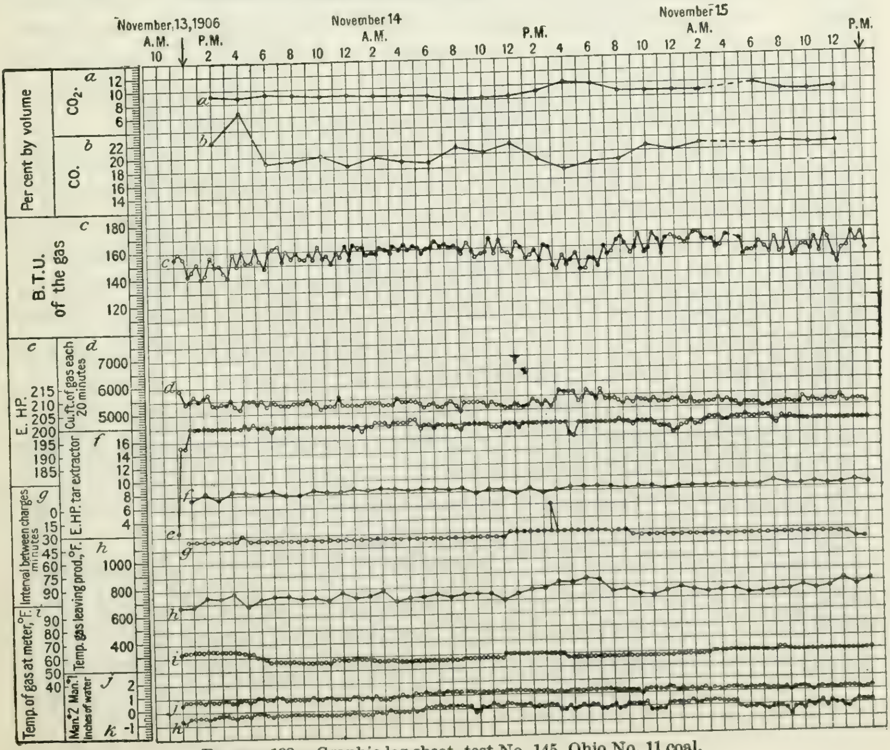


FIGURE 138.—Graphic log sheet, test No. 145, Ohio No. 11 coal.

of use for 9 hours by the breaking of its driving belt. No serious trouble was caused at the engine by tar during this period, but to avoid any possible accumulation of this substance the meter was by-passed for the remainder of the run. The test lasted 50 hours, with full load. Graphic log is given on page 185.

PENNSYLVANIA.

Pennsylvania No. 4, test 65.—Pennsylvania No. 4 coal in nut size gave satisfaction. It made a gas of uniform composition with an average heat value of 141 B. t. u. per cubic foot. There were no clinkers, and the bed was easily kept in uniform condition. Graphic log is given on page 186.

Pennsylvania No. 5B, test 59.—In the $\frac{3}{4}$-inch size used, Pennsylvania No. 5B coal required frequent poking to keep the fuel bed in good condition. The gas was not uniform in composition, but had an average heat value of 149 B. t. u. per cubic foot. The standard 50-hour test was made with full load. Graphic log is given on page 186.

Pennsylvania No. 6, test 66.—Pennsylvania No. 6 was a run-of-mine coal which had been crushed and washed. It worked well in the producer, but the heat value of the gas was low, averaging 127 B. t. u. per cubic foot. Graphic log is given on page 187.

Pennsylvania Nos. 6A and 6B, test 70.—A mixture of Pennsylvania Nos. 6A and 6B was an entirely satisfactory fuel, making a gas of uniform composition with an average heat value of 146 B. t. u. per cubic foot. For the first 16 hours of the run 150 pounds of coal were charged every 35 minutes, and during the remainder of the test 150 pounds were charged every 40 minutes. The standard 50-hour test was made with full load. Graphic log is given on page 188.

Pennsylvania No. 7, test 88.—Pennsylvania No. 7 was an exceedingly friable coal. The sample used in this test had been stored in an uncovered bin on the ground for about 3½ months, and as a result a large part of it was slack. The gas, although it had an average heat value of 139 B. t. u. per cubic foot, was of such poor quality that the load on the engine had to be reduced. It was difficult to keep the fuel bed in good condition, and the amount of ash produced was exceptionally large. Graphic logs are given on page 189.

Pennsylvania No. 8, test 63.—Pennsylvania No. 8 run-of-mine coal proved to be an excellent producer fuel, making a satisfactory gas with an average heat value of 133 B. t. u. per cubic foot. A minor difficulty with the engine interrupted the test from 1 to 2 a. m., September 22, as shown by the graphic log, page 189.

Pennsylvania No. 10, test 71.—Pennsylvania No. 10 was a satisfactory producer coal. At the start of the 50-hour run the fuel bed was a little low, but it was soon brought to the proper height, after which coal was charged regularly every 40 minutes. The heat value of the

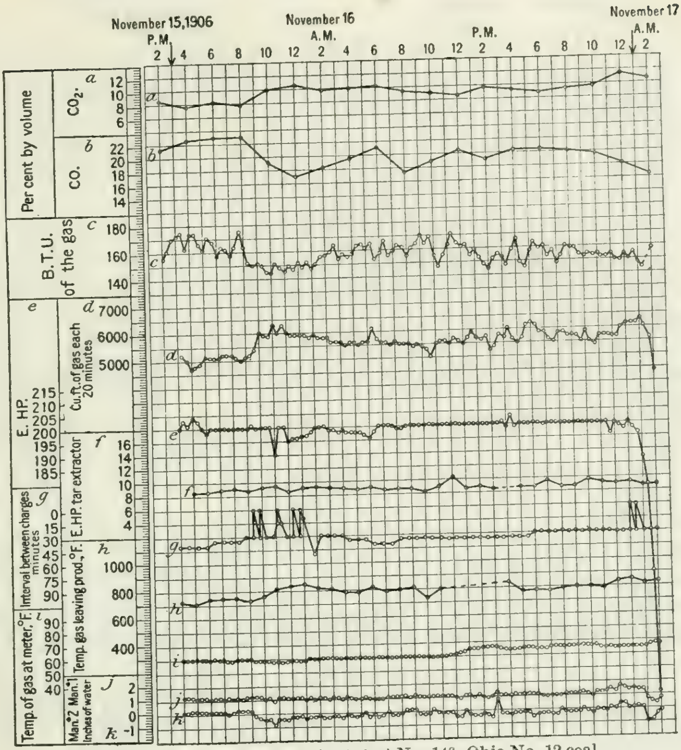


FIGURE 139.—Graphic log sheet, test No. 146, Ohio No. 12 coal.

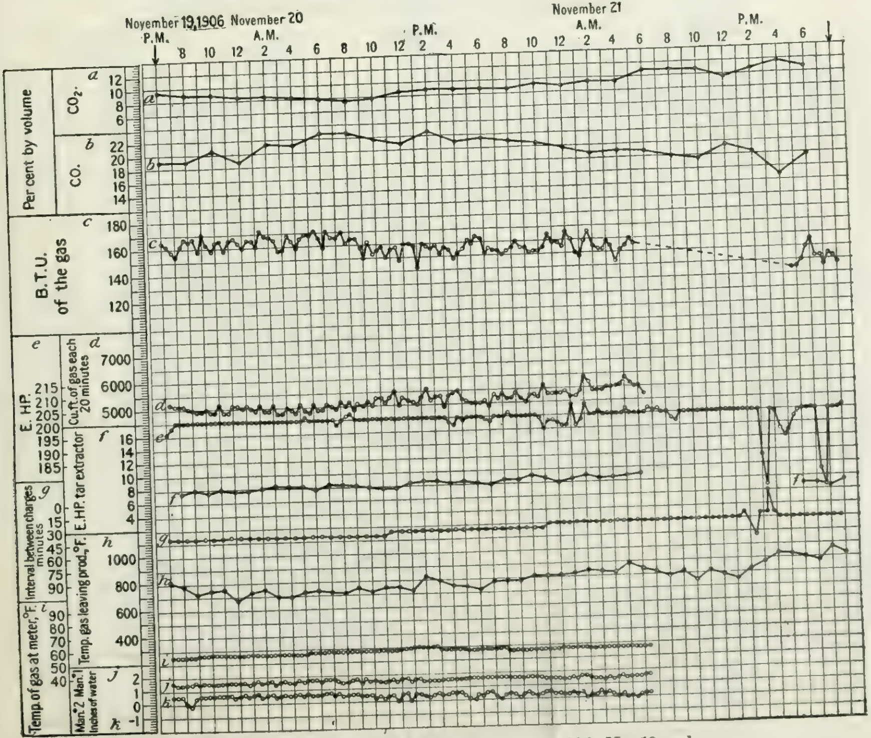
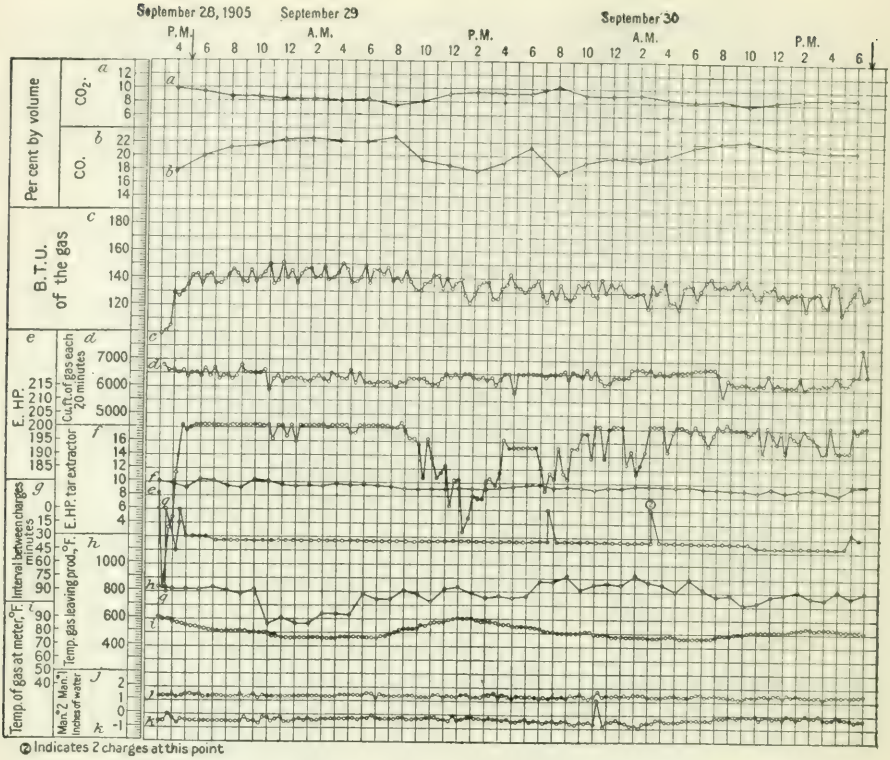


FIGURE 140.—Graphic log sheet, test No. 147, Ohio No. 12 coal.



⊙ Indicates 2 charges at this point

FIGURE 141.—Graphic log sheet, test No. 65, Pennsylvania No. 4 coal.

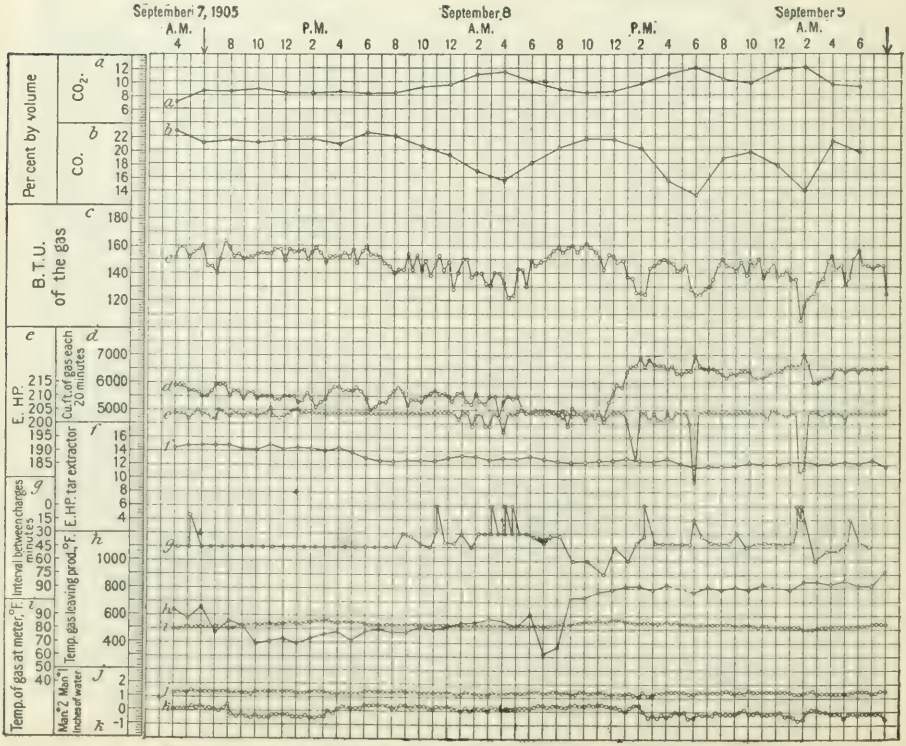
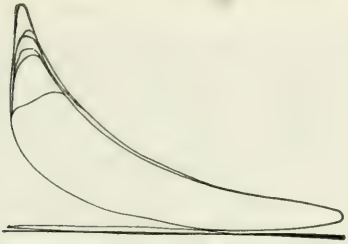
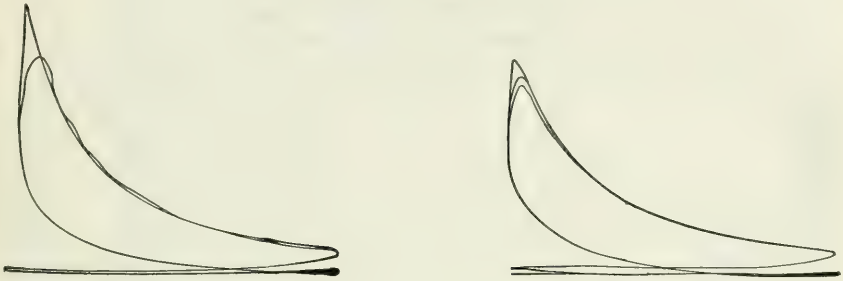


FIGURE 142.—Graphic log sheet, test No. 59, Pennsylvania No. 5B coal.



Center cylinder, M. E. P., 64; Max., 250; Rel., 42;
I. H. P., 102.2.



Right cylinder, M. E. P., 66; Max., 300; Rel., 36;
I. H. P., 105.4.

Left cylinder, M. E. P., 60; Max., 240; Rel., 38;
I. H. P., 95.8.

FIGURE 143.—Indicator cards, test No. 59, Pennsylvania No. 5B coal. Scale of spring, 80; revolutions per minute, 202.6.

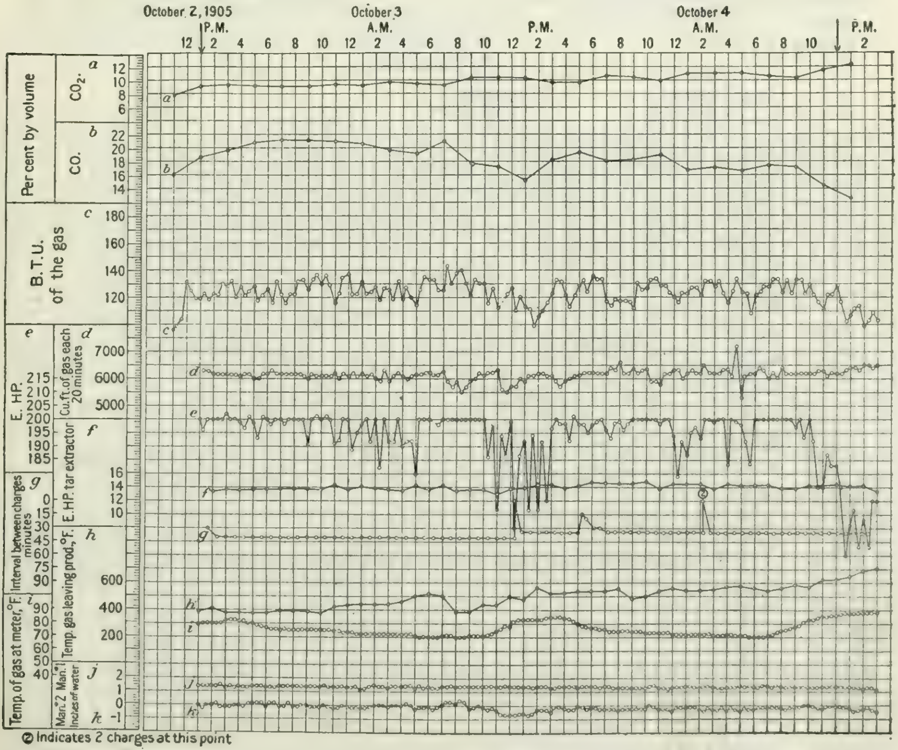
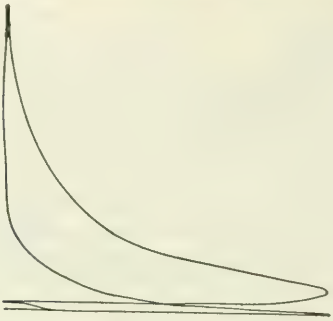
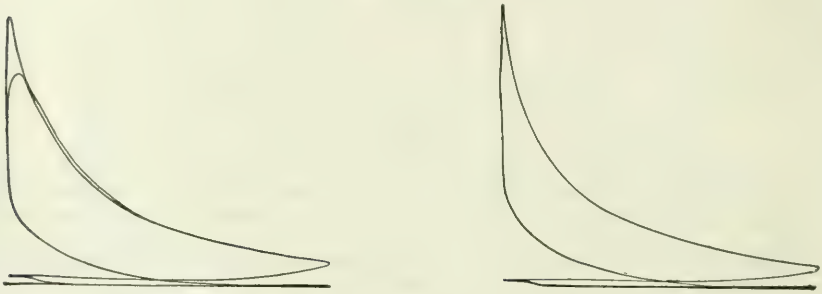


FIGURE 144.—Graphic log sheet, test No. 6, Pennsylvania No. 6 coal.



Center cylinder. M. E. P., 66; Max., 330; Rel., 40; I. H. P., 104.5.



Right cylinder. M. E. P., 66; Max., 290; Rel., 38; I. H. P., 104.5.

Left cylinder. M. E. P., 62; Max., 320; Rel., 38; I. H. P., 98.2.

FIGURE 145.—Indic nnsylvania No. 6 coal. Scale of spring, 80; revolutions per minute, 201.0.

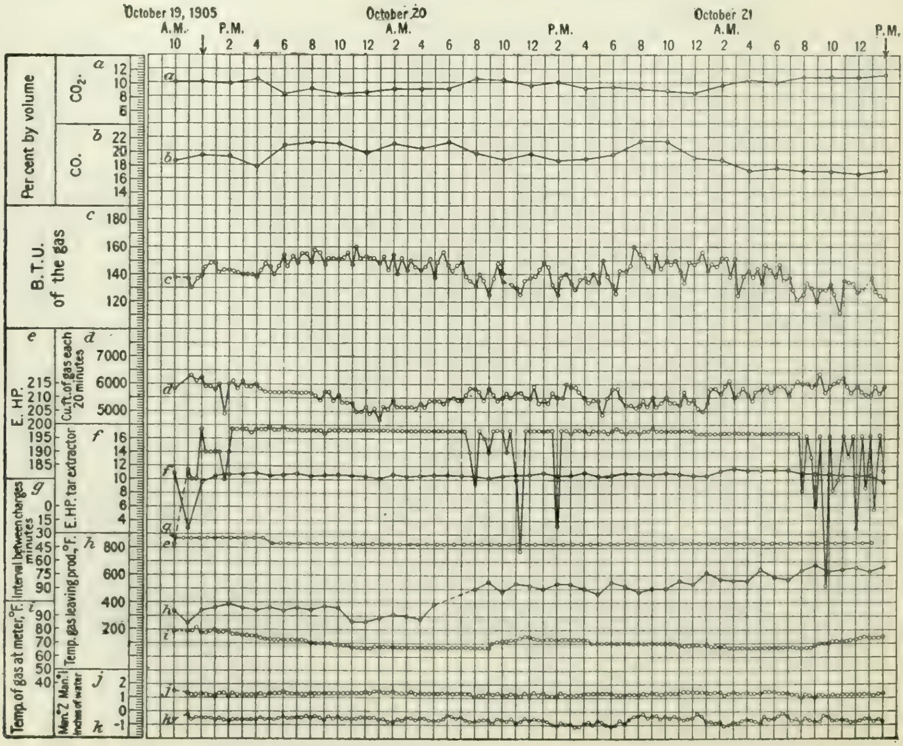


FIGURE 146.—Graphic log sheet, test No. 70, Pennsylvania No. 6A and 6B coal.

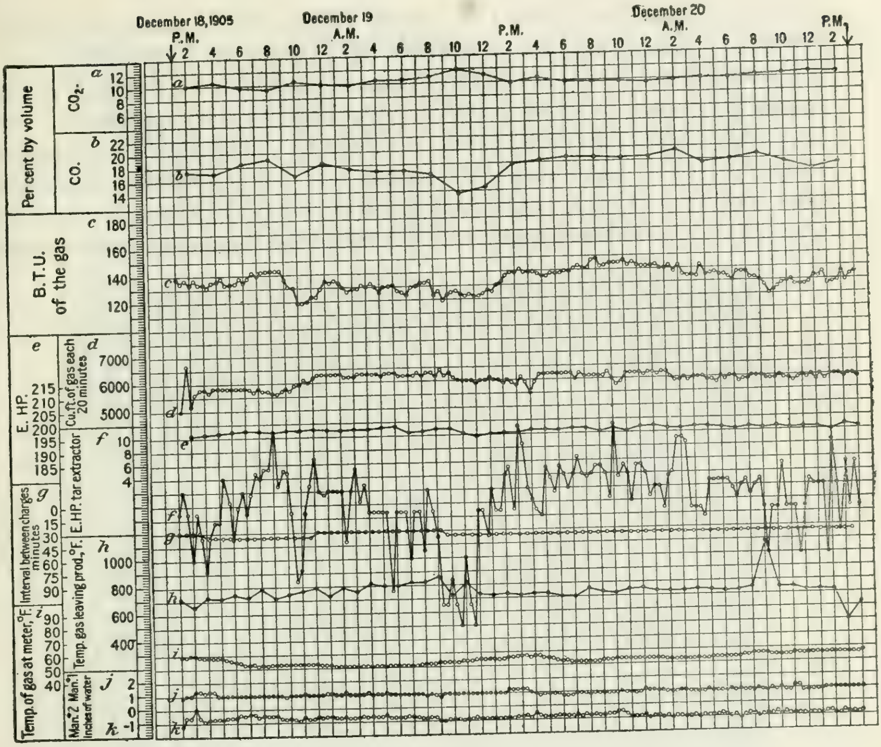
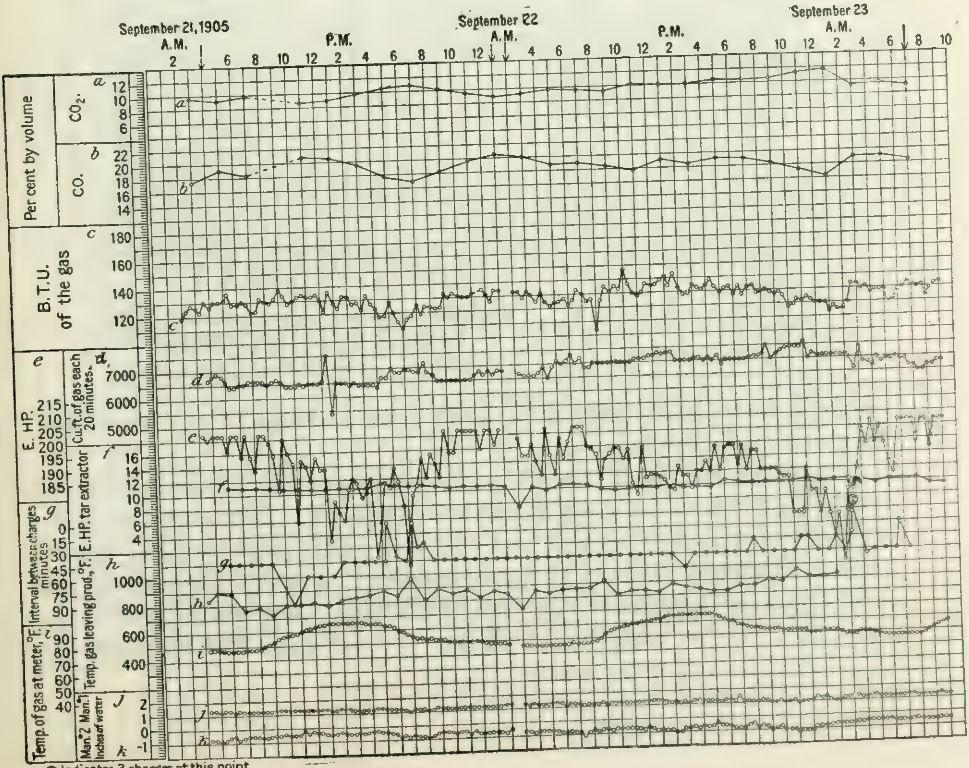


FIGURE 147.—Graphic log sheet, test No. 88, Pennsylvania No. 7 coal.



② Indicates 2 charges at this point

FIGURE 148.—Graphic log sheet, test No. 63, Pennsylvania No. 8 coal.

gas was higher than that from most Pennsylvania coals, averaging 159 B. t. u. per cubic foot. Graphic log is given on page 190.

Pennsylvania No. 11, test 129.—Pennsylvania No. 11, a bright, clean-appearing coal, worked remarkably well in the producer. An unusually thick fuel bed, about 5½ feet in depth, gave no trouble whatever. The heat value of the gas was fairly uniform and averaged 146 B. t. u. per cubic foot for the run of 50 hours. As there was no steaming test made on this coal, the apparent evaporation was calculated as explained in the footnote on page 123. Graphic log is given on page 191.

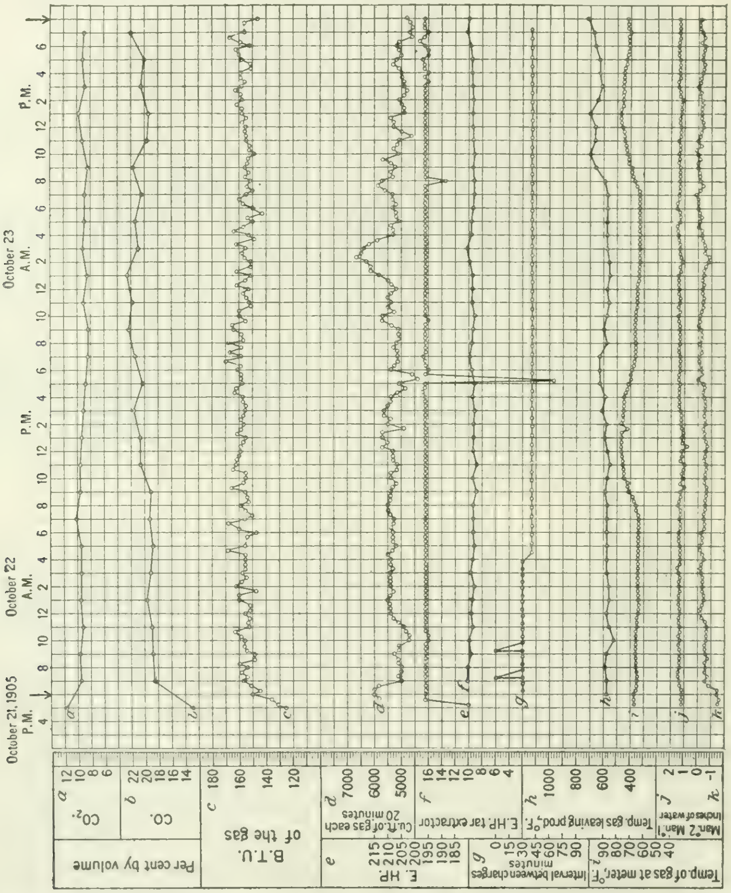


FIGURE 149.—Graphic log sheet, test No. 71, Pennsylvania No. 10 coal.

Pennsylvania No. 12, test 143.—Pennsylvania No. 12, a run-of-mine coal, gave satisfactory results in the producer. There were no indications of clinker and the fuel bed was easily kept in good condition. The heat value of the gas gradually increased throughout the run and averaged 148 B. t. u. per cubic foot. The quantity of available fuel limited the test to 28 hours. As there was no steaming

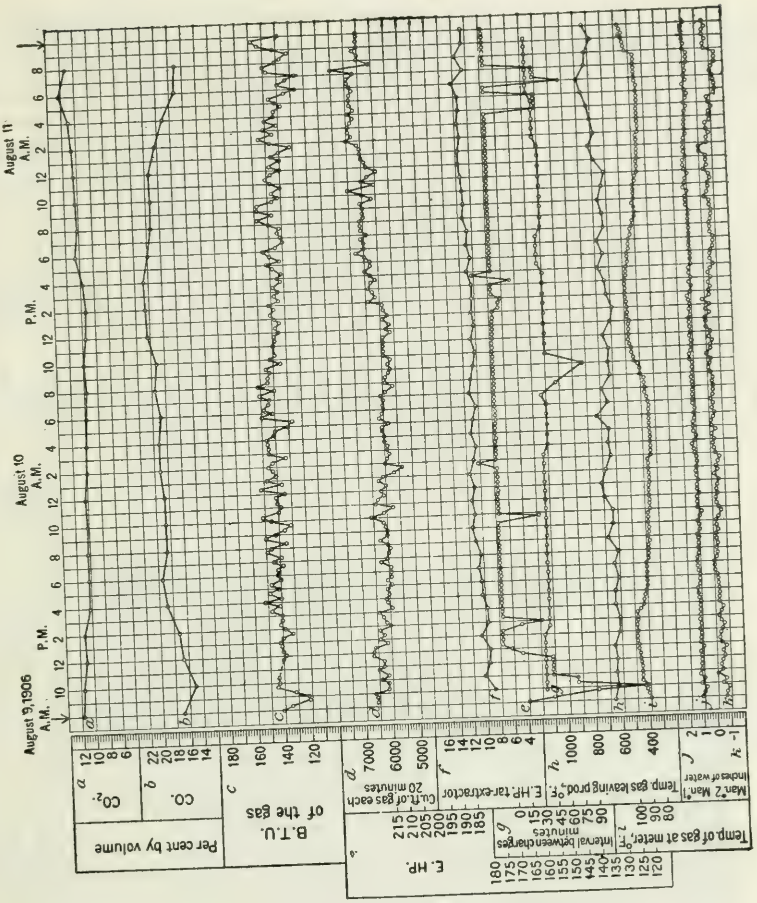


FIGURE 150.—Graphic log sheet, test No. 129, Pennsylvania No. 11 coal.

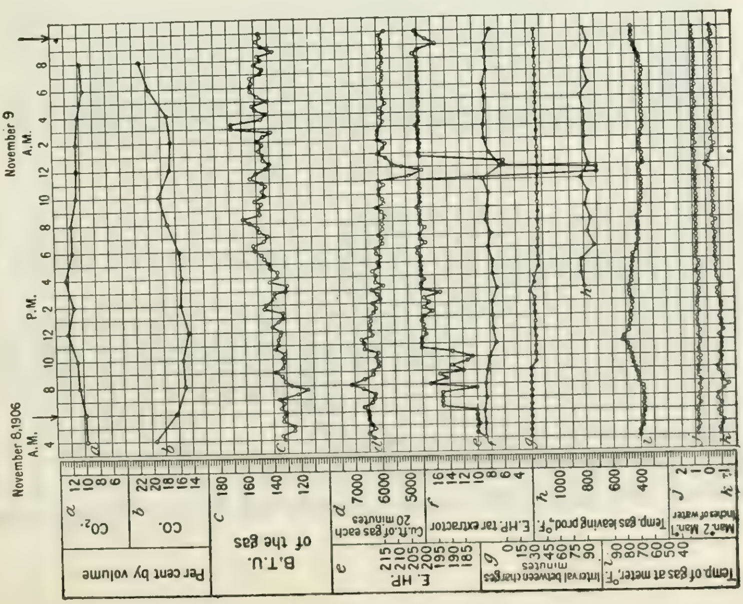


FIGURE 151.—Graphic log sheet, test No. 143, Pennsylvania No. 12 coal.

test made on this coal, the apparent evaporation was calculated as explained in the footnote on page 123. Graphic log is given on page 191.

Pennsylvania No. 13, test 136.—This fuel, a clean run-of-mine coal, gave satisfactory results in the producer. The test was started with the fuel bed in rather poor condition, but this was readily improved. The coal had a slight tendency to fuse, but no serious difficulty was caused. The gas was of fairly uniform composition and had an average heat value of 153 B. t. u. per cubic foot during the run of 50 hours. Toward the end of the test the tar-extractor shaft broke; consequently during the remainder of the run the gas meter was by-passed. As there was no steaming test made on this coal, the apparent evaporation was calculated as explained in the footnote on page 123. Graphic log is given on page 192.

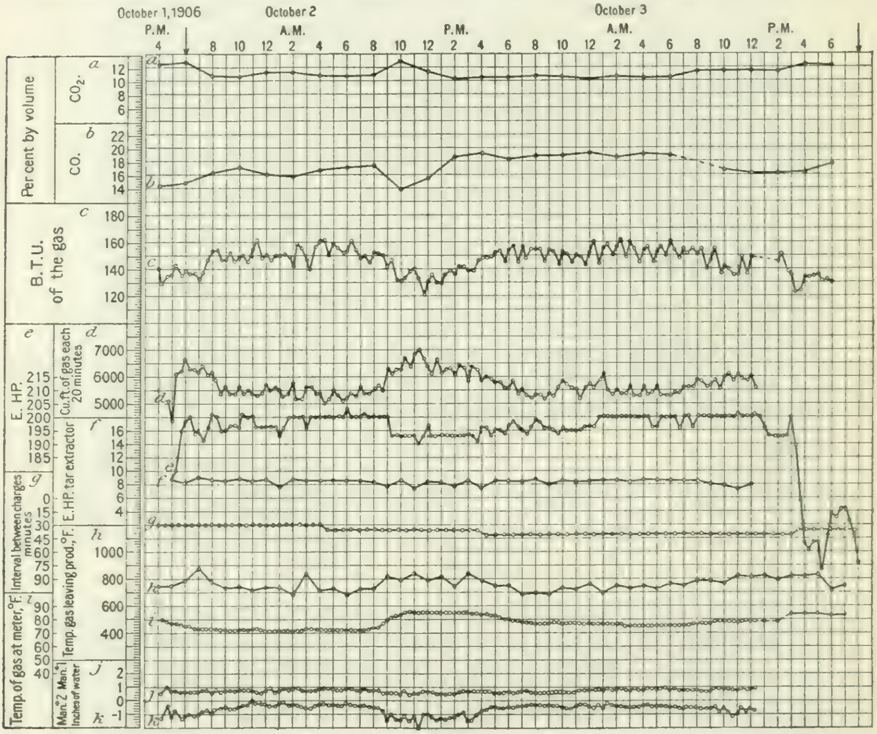


FIGURE 152.—Graphic log sheet, test No. 136, Pennsylvania No. 13 coal.

Pennsylvania No. 13, test 140.—Pennsylvania No. 13 was an average-appearing run-of-mine coal containing considerable slack. The fuel bed required a great deal of poking, although there seemed to be no tendency to clinker. The gas was variable in composition and at times dropped 15 to 20 B. t. u. per cubic foot in heat value. The average heat value, however, was 145 B. t. u. per cubic foot. A full 50-hour test was made, with approximately full load. The apparent

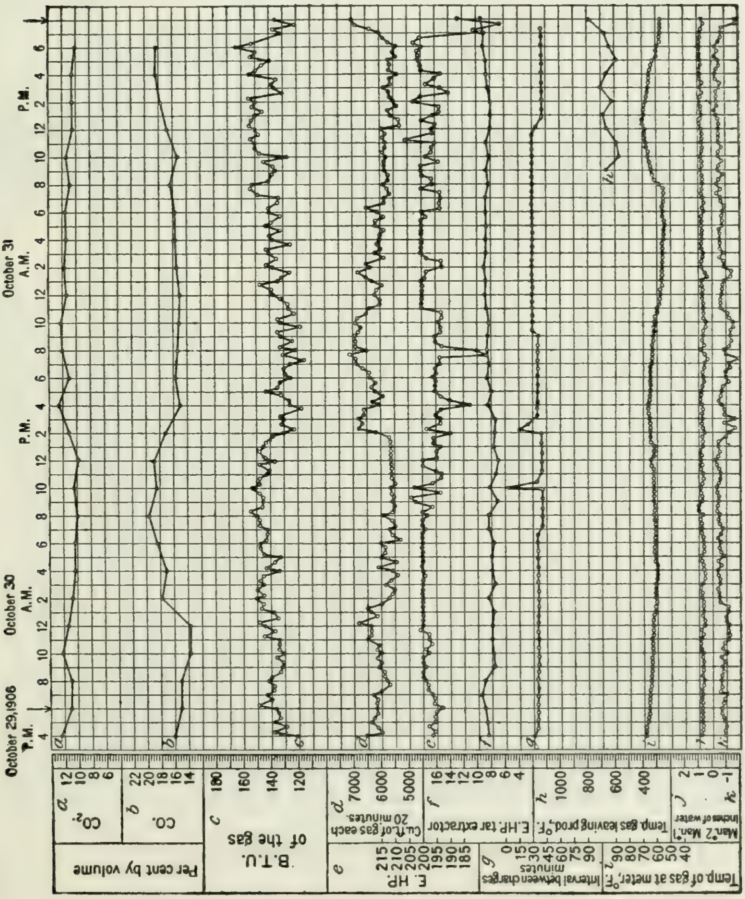


FIGURE 153.—Graphic log sheet, test No. 140, Pennsylvania No. 13 coal.

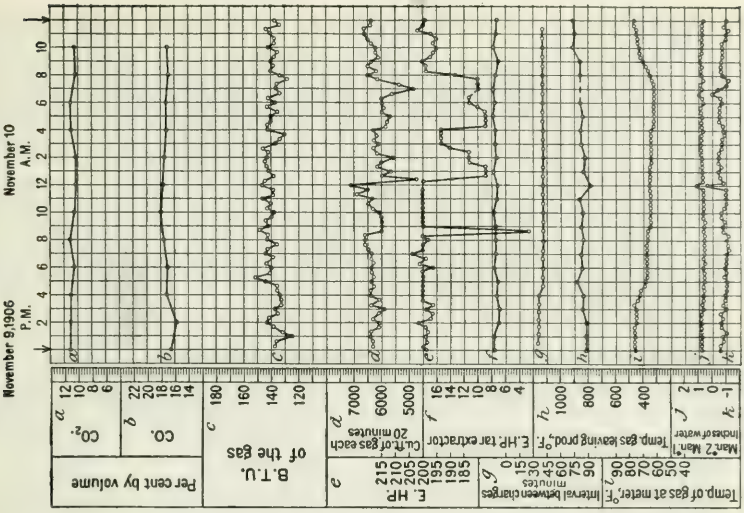


FIGURE 154.—Graphic log sheet, test No. 144, Pennsylvania No. 15 coal.

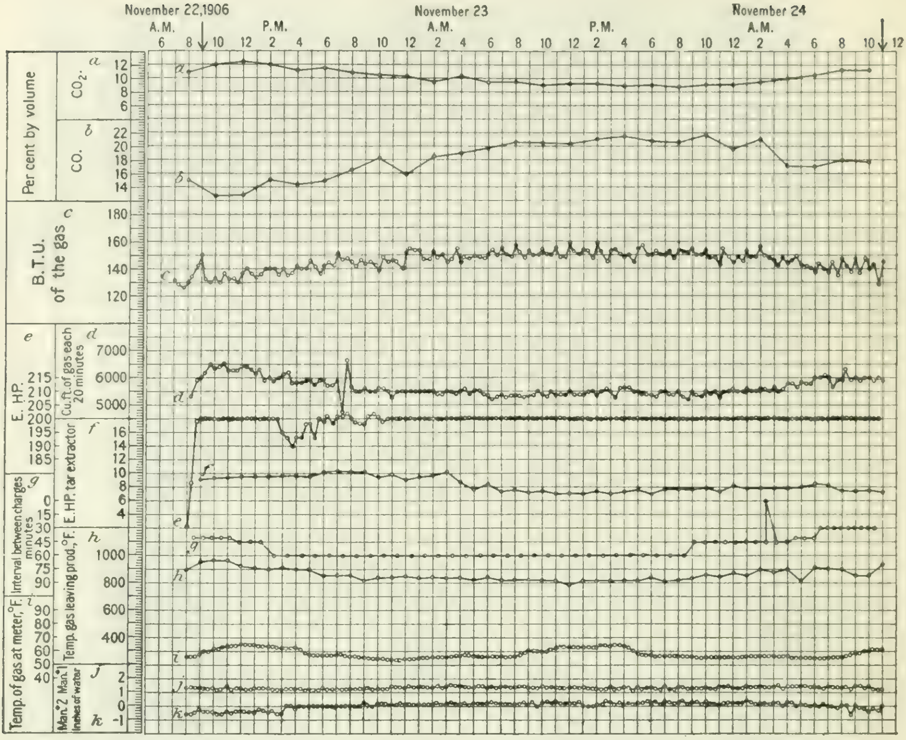


FIGURE 155.—Graphic log sheet, test No. 148, Pennsylvania No. 16 coal.

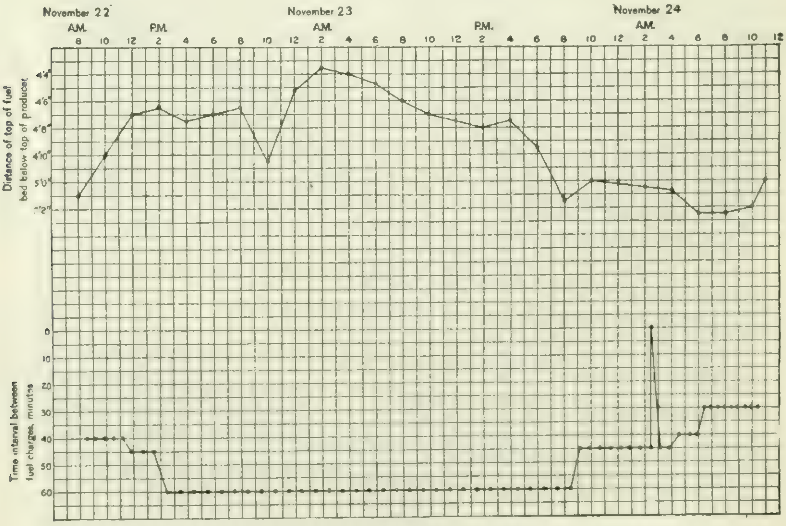


FIGURE 156.—Charging record, test No. 148, Pennsylvania No. 16 coal.

evaporation was calculated as explained in the footnote on page 123. Graphic log is given on page 193.

Pennsylvania No. 15, test 144.—Pennsylvania No. 15 was a clean-appearing run-of-mine coal, a considerable proportion of which was slack. It worked satisfactorily. The heat value of the gas was fairly uniform and averaged 144 B. t. u. per cubic foot. During the run one of the field coils in the electric generator gave a little trouble, for a time necessitating a reduction in the load. The average load for the test, nevertheless, was 96 per cent of full load. Owing to lack of coal the test lasted only 24 hours. Graphic log is given on page 193.

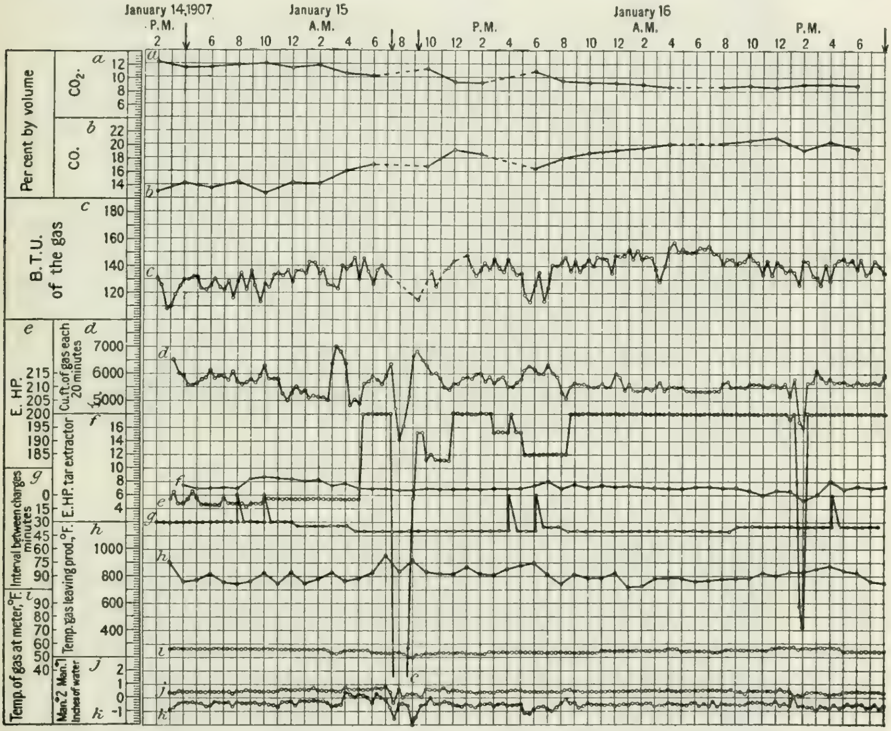


FIGURE 157.—Graphic log sheet, test No. 158, Pennsylvania No. 17 coal.

Pennsylvania No. 16, test 148.—Pennsylvania No. 16 was a clean-appearing run-of-mine coal containing a high percentage of slack. It worked well, but required frequent poking. The gas was quite uniform in composition and had an average heat value of 150 B. t. u. per cubic foot. A steady full load was easily maintained throughout the standard 50-hour test. Graphic log is given on page 194.

Pennsylvania No. 17, test 158.—Pennsylvania No. 17 was a run-of-mine coal containing a large amount of very fine slack. During the first part of the test this coal did not work satisfactorily on account

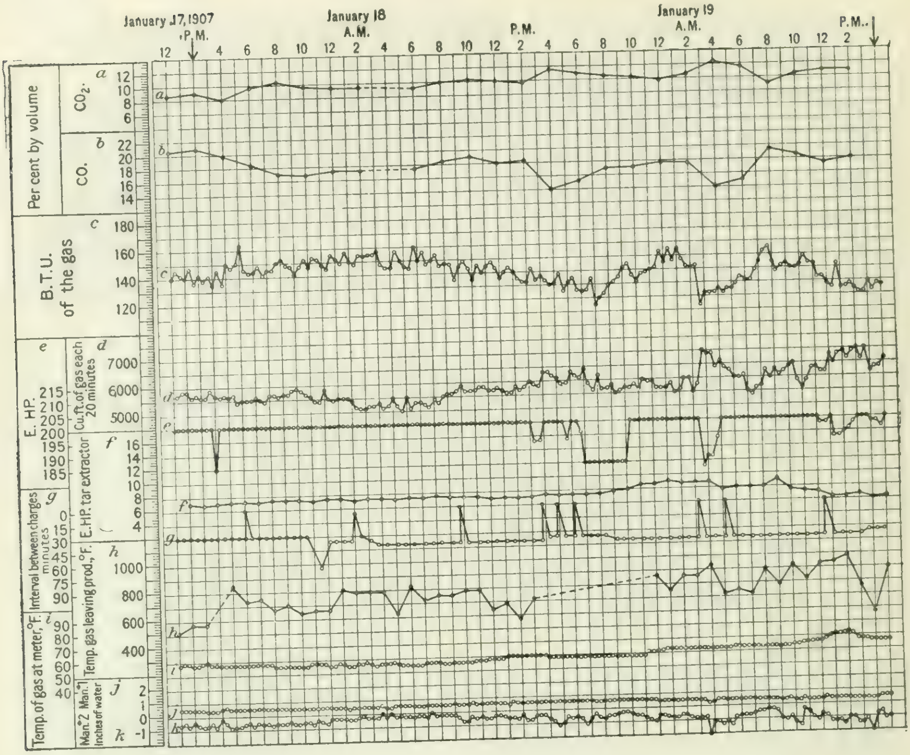
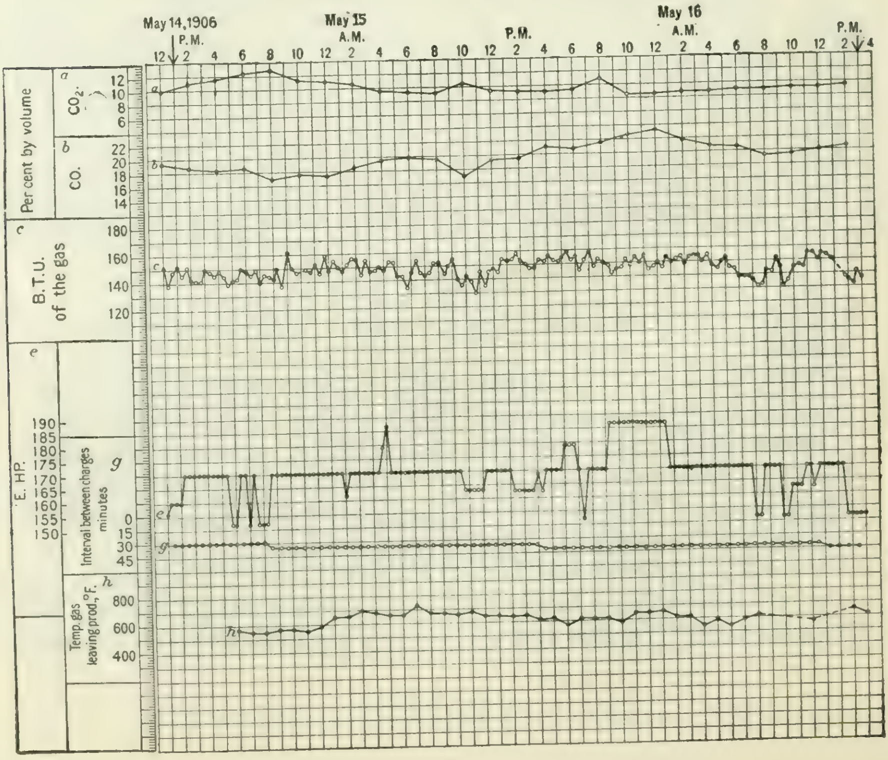


FIGURE 158.—Graphic log sheet, test No. 159, Pennsylvania No. 22 coal.



of the formation of channels in the fuel bed. After about 15 hours the fuel bed was in much better condition, and it was kept under control during the rest of the run. The gas was fairly uniform in composition and had an average heat value of 141 B. t. u. per cubic foot. The test lasted 50 hours, with approximately 90 per cent of full load. Graphic log is given on page 195.

Pennsylvania No. 22, test 159.—The fuel for this test included very little slack, and was in excellent shape for the producer. The gas was of fairly uniform composition and had an average heat value of 166 B. t. u. per cubic foot. The test lasted 50 hours, with a steady full load. During the last half of the run the fuel bed gave considerable trouble on account of clinker and the formation of blowholes. Frequent poking helped remedy the difficulty, but did not entirely overcome it. As there was no steaming test on this coal the apparent evaporation was calculated by the formula as explained in the footnote on page 123. Graphic log is given on page 196.

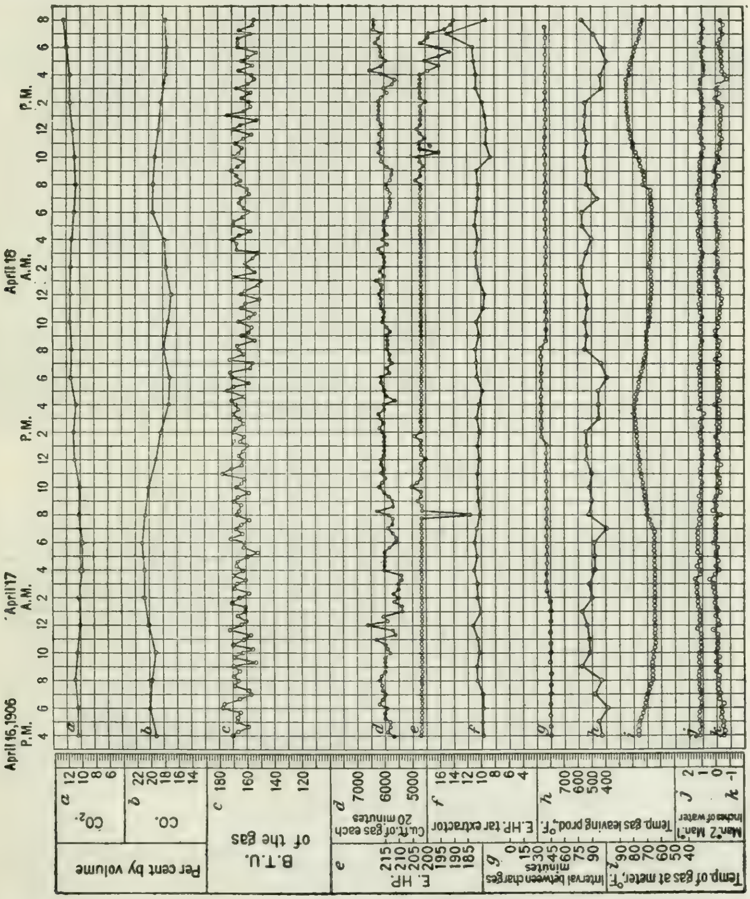


FIGURE 160.—Graphic log sheet, test No. 107, Tennessee No. 2 coal.

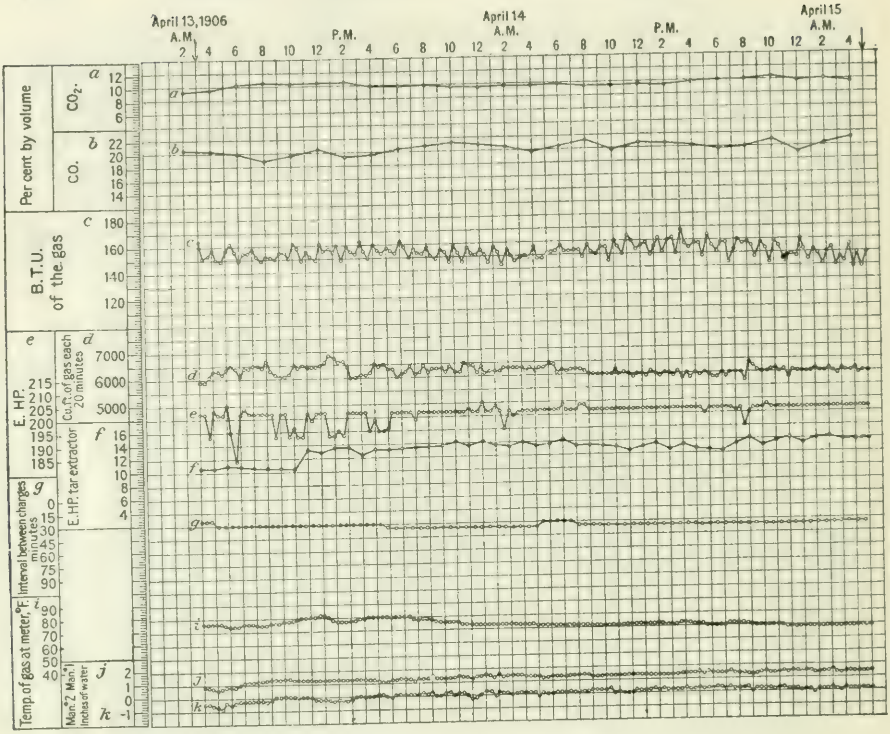


FIGURE 161.—Graphic log sheet, test No. 106, Tennessee No. 3 coal.

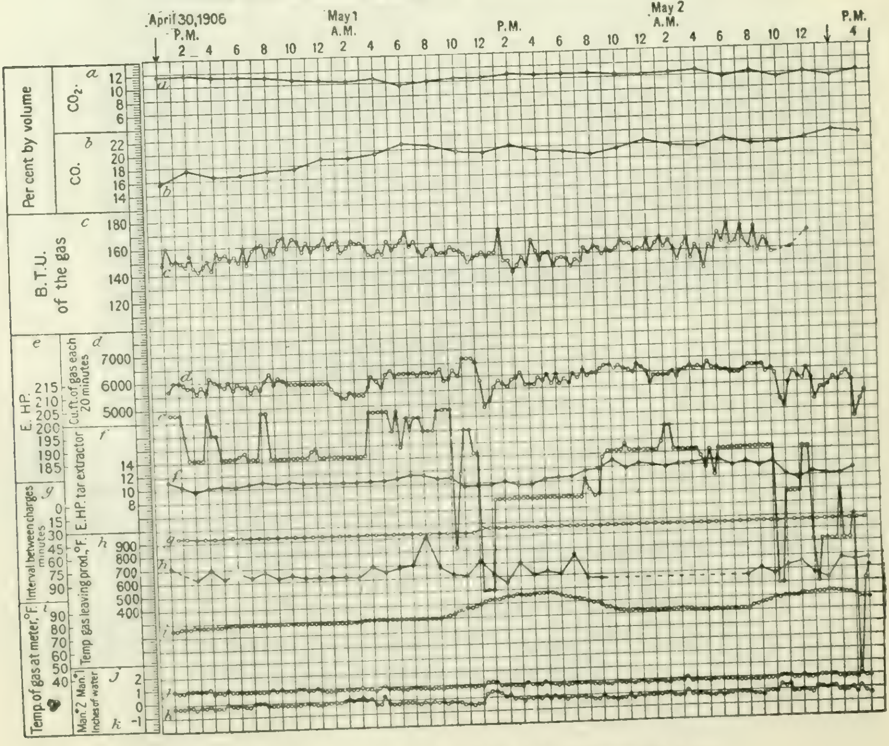


FIGURE 162.—Graphic log sheet, test No. 111, Tennessee No. 4 coal.

RHODE ISLAND.

Rhode Island No. 1, test 113.—Rhode Island No. 1 was a graphitic coal having a gray, metallic appearance. Some of the lumps were extremely hard, but others were soft. This material was charged on top of a good fuel bed of Tennessee coal capable of making a gas of average quality. As the charging continued, the heat value of the gas steadily decreased, whereas the temperature of the fuel bed increased. After 15 hours the calorimeter would not work because of the low heat value of the gas, which at that time was about 55 B. t. u. per cubic foot. Three hours later the engine stopped and subsequent attempts to start it again were unsuccessful.

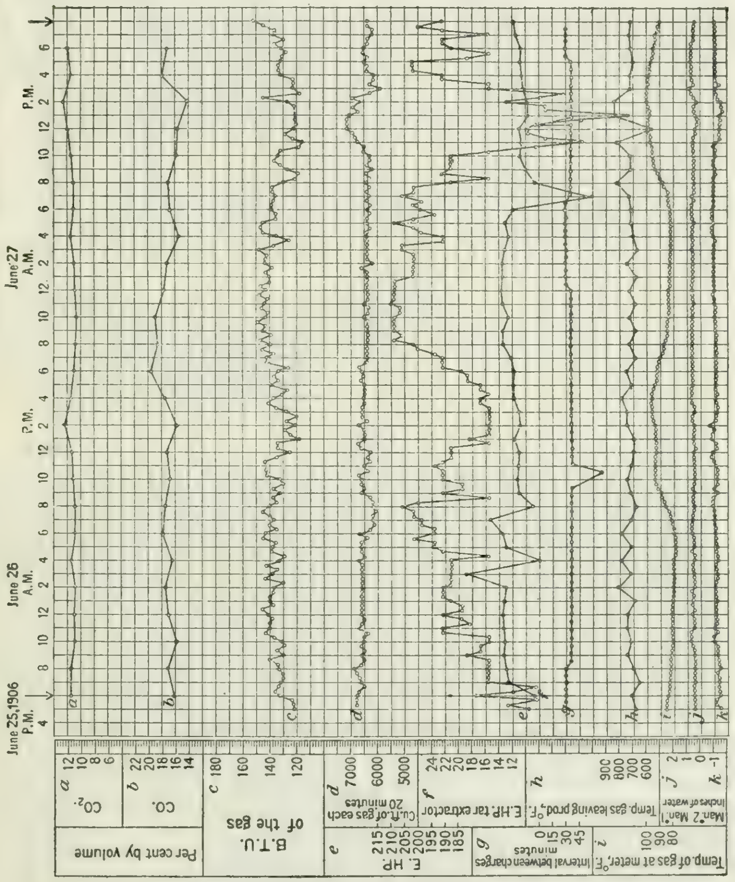


FIGURE 163.—Graphic log sheet, test No. 125, Tennessee No. 5 coal.

TENNESSEE.

Tennessee No. 1, test 115.—Tennessee No. 1 was a bright, clean-appearing coal which had a tendency to fuse, making it difficult to keep the fuel bed in good condition. It gave a gas of fairly uniform composition, with an average heat value of 155 B. t. u. per cubic foot.

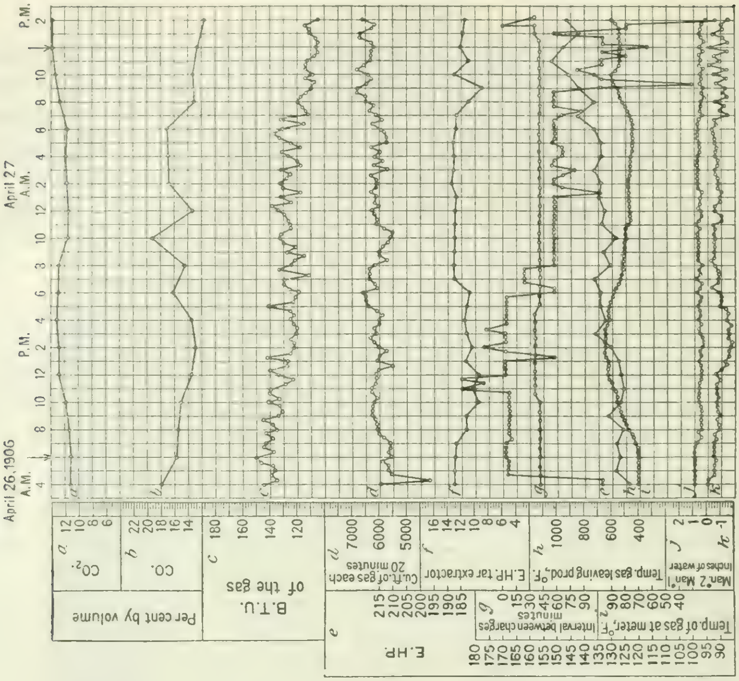
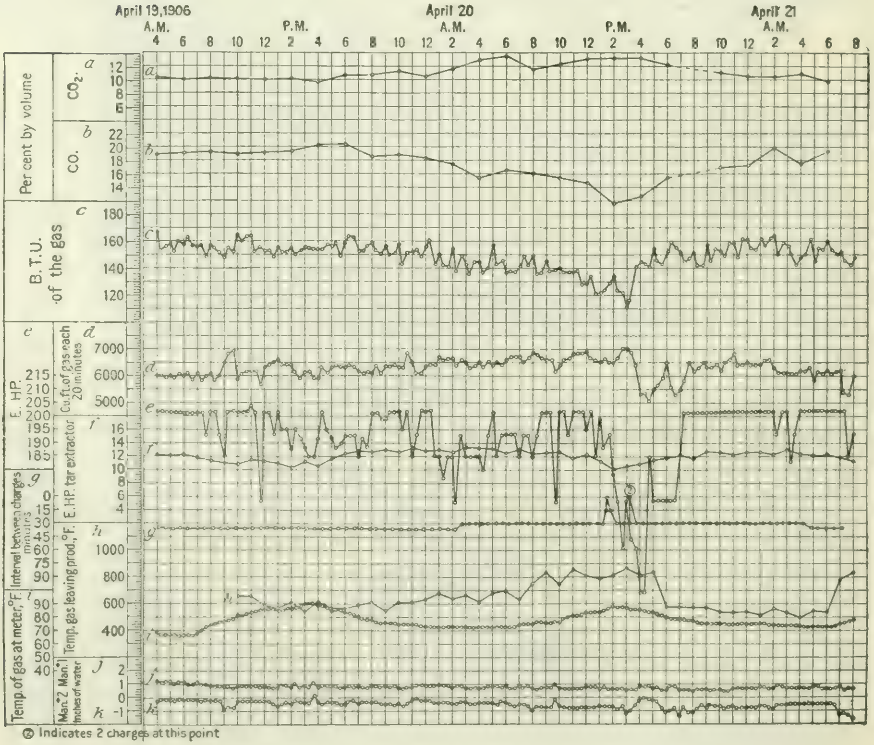


FIGURE 161.—Graphic log sheet, test No. 110, Tennessee No. 6 coal.



② Indicates 2 charges at this point

FIGURE 165.—Graphic log sheet, test No. 108, Tennessee No. 7A coal.

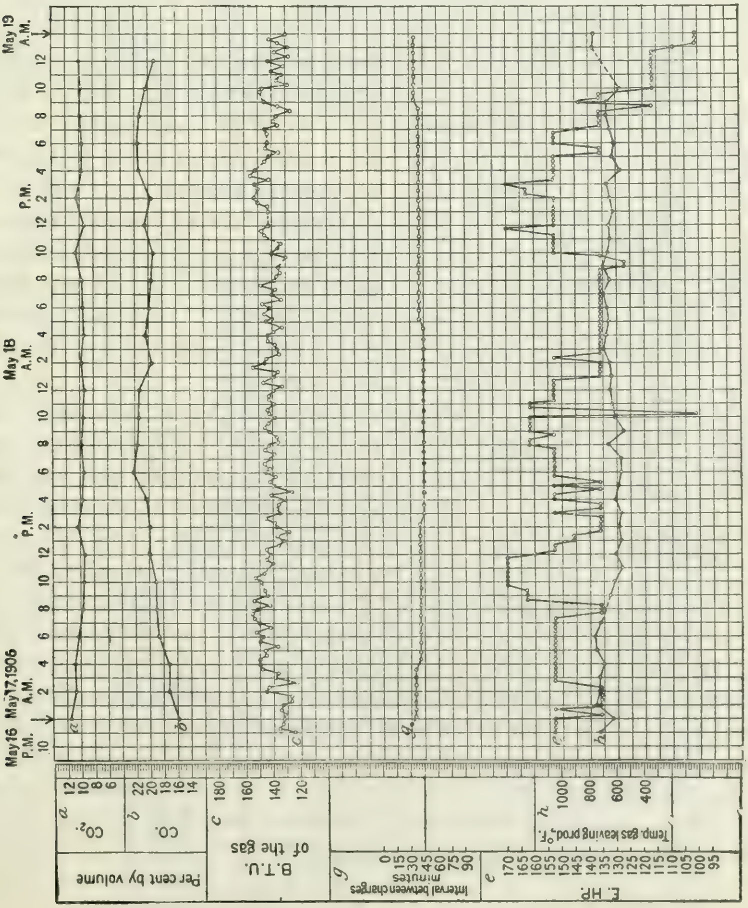


FIGURE 166.—Graphic log sheet, test No. 116, Tennessee Nos. 8A and 8B coal.

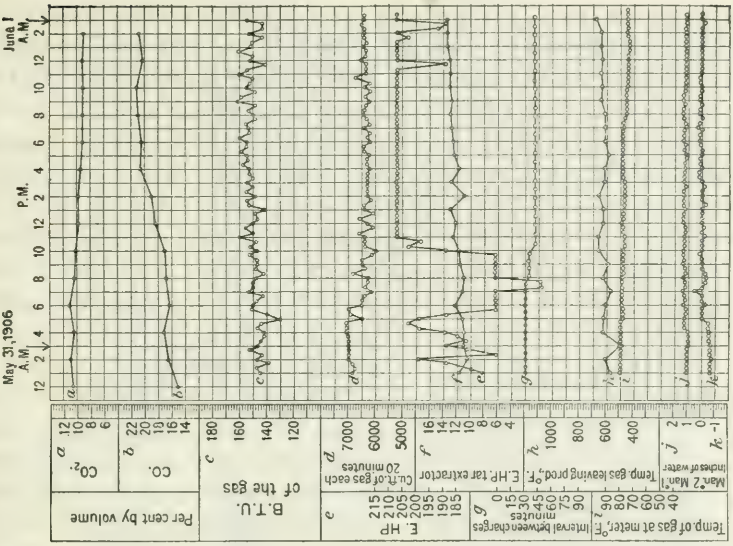


FIGURE 167.—Graphic log sheet, test No. 119, Tennessee Nos. 8A and 8B coal.

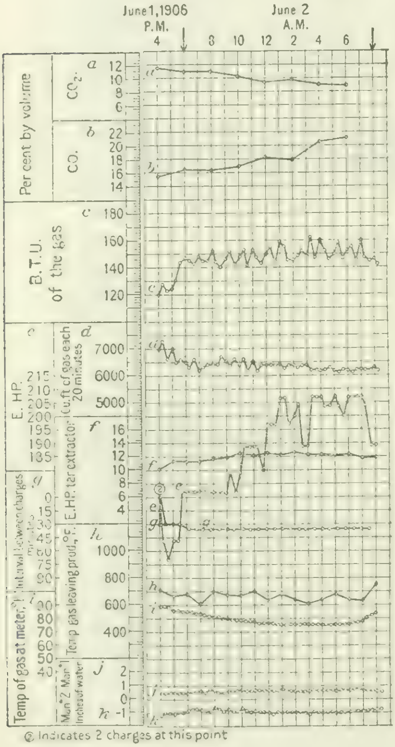
The entire test was run without the tar extractor, and to avoid clogging the gas meter was by-passed. The full 50-hour test was made with about 85 per cent of full load. Graphic log is given on page 196.

Tennessee No. 2, test 107.—Tennessee No. 2 coal gave an exceptionally good test, working well and yielding a gas with an average heat value of 168 B. t. u. per cubic foot. Full load was carried throughout the 50-hour run. Graphic log is given on page 197.

Tennessee No. 3, test 106.—Tennessee No. 3 coal proved satisfactory. The gas was of fairly uniform composition and had a heat value averaging 160 B. t. u. per cubic foot. The test lasted 50 hours with full load. Graphic log is given on page 198.

Tennessee No. 4, test 111.—Tennessee No. 4, a clean, bright, run-of-mine coal, was so fine when used as to be almost a slack The heat value of the gas averaged 162 B. t. u. per cubic foot and was fairly uniform. The water supply for the engine varied considerably and much of the time was insufficient. On this account the engine could not carry full load during the entire test. An accident to the motor put the tar extractor out of use during the last 12 hours of the run. The uncleaned gas, although it gave some trouble, did not cause a shutdown. A full 50-hour test was made. Graphic log is given on page 198.

Tennessee No. 5, test 125.—Tennessee No. 5, a bright, clean coal, mostly slack, worked well and gave no indications of clinkering. The fuel bed had a tendency to become too hot and required close watching. The heat value of the gas was fairly uniform and averaged 142 B. t. u. per cubic foot. The regulation 50-hour test was made, with about 90 per cent of full load. Graphic log is given on page 199.



② Indicates 2 charges at this point

FIGURE 108.—Graphic log sheet, test No. 119A, Tennessee Nos. 8A and 8B coal.

Tennessee No. 6, test 110.—Tennessee No. 6, a clean-appearing coal, worked well. It gave a gas which fluctuated considerably in composition. The average heat value of the gas was 133 B. t. u. per cubic foot for the 30-hour run. On account of the low pressure in the water main supplying the engine jackets, full load could not be carried. Graphic log is given on page 200.

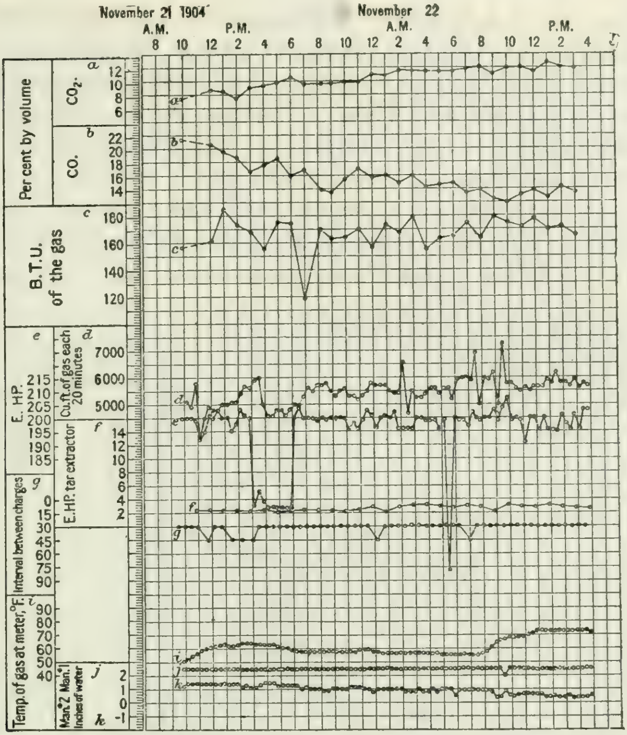


FIGURE 169.—Graphic log sheet, test No. 11, Texas No. 1 coal.

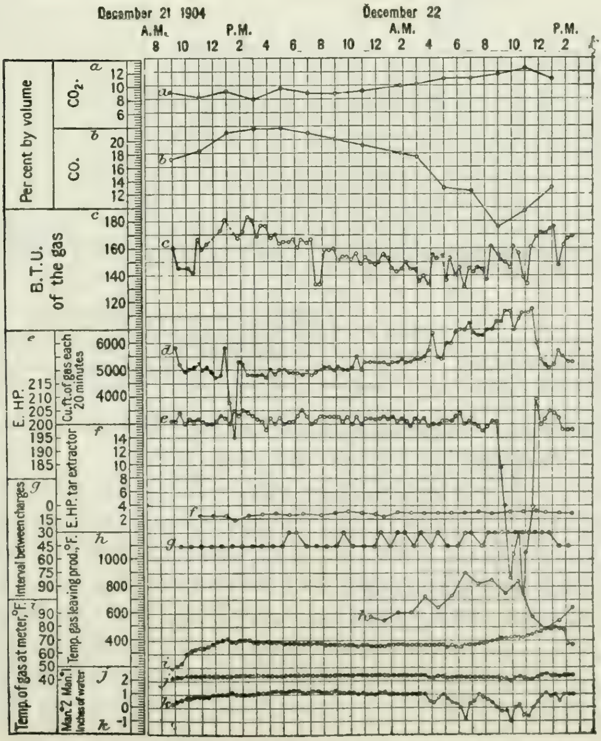


FIGURE 170.—Graphic log sheet, test No. 18, Texas No. 2 coal.

Tennessee No. 7A, test 108.—Tennessee No. 7A, a clean, bright coal, worked well during the first part of the run. The producer began to heat, however, and became very hot; the blast pressure increased and blowholes formed in the fuel bed. The heat value of the gas decreased from about 140 B. t. u. to 110 B. t. u. per cubic foot, and the load was reduced to about two-thirds full load. At this point the ash bed was ground down and the fuel bed was thoroughly poked and loosened up. The heat value of the gas began to increase at once, and after 5 hours conditions were normal, so that full load was put on. There was no further difficulty during the remainder of the 50-hour run. Graphic log is given on page 200.

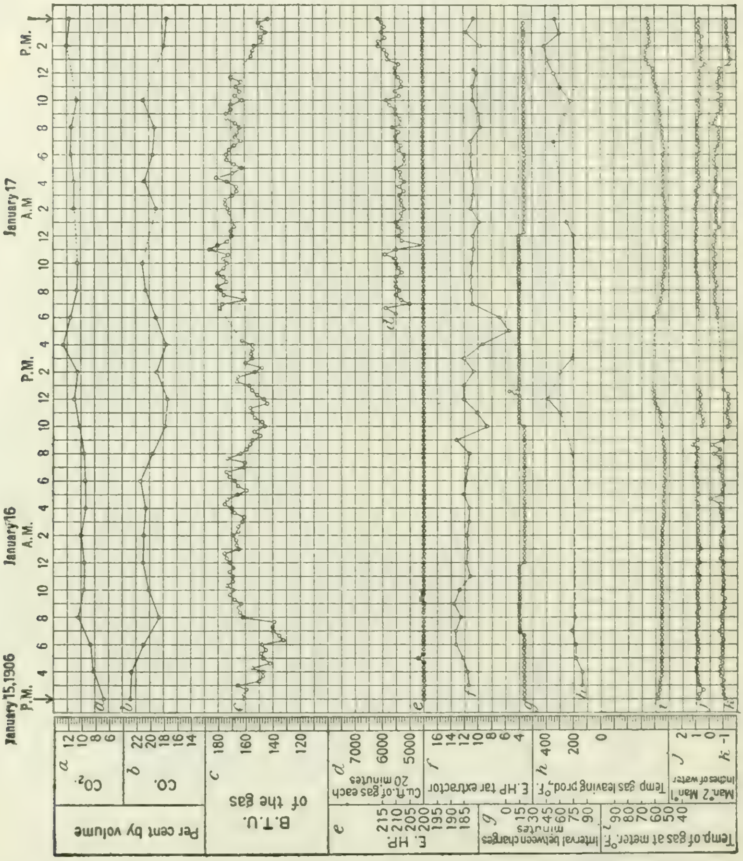


FIGURE 171.—Graphic log sheet, test No. 93, Texas No. 3 coal.

Tennessee Nos. 8A and 8B, test 116.—This coal was to all appearances similar to Tennessee No. 1, except that it was washed. The fuel bed was kept in good condition with some difficulty, but the gas was fairly uniform in composition and had an average heat value of 147 B. t. u. per cubic foot. The test was made without running the tar extractor, the gas meter being by-passed. The run lasted 50 hours, with about three-fourths full load. Graphic log is given on page 201.

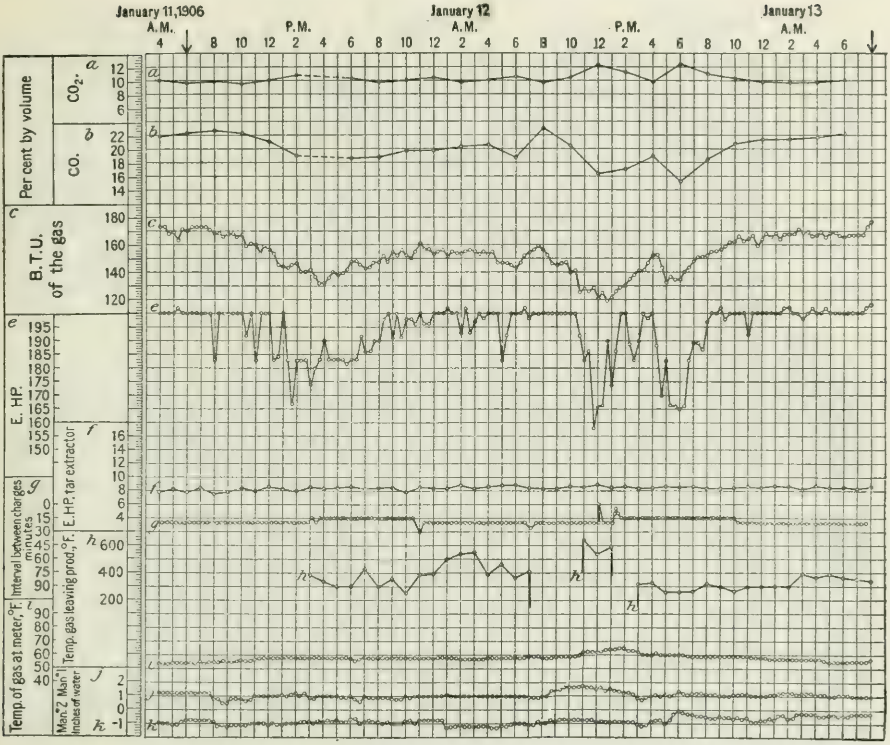


FIGURE 172.—Graphic log sheet, test No. 92, Texas No. 4 coal.

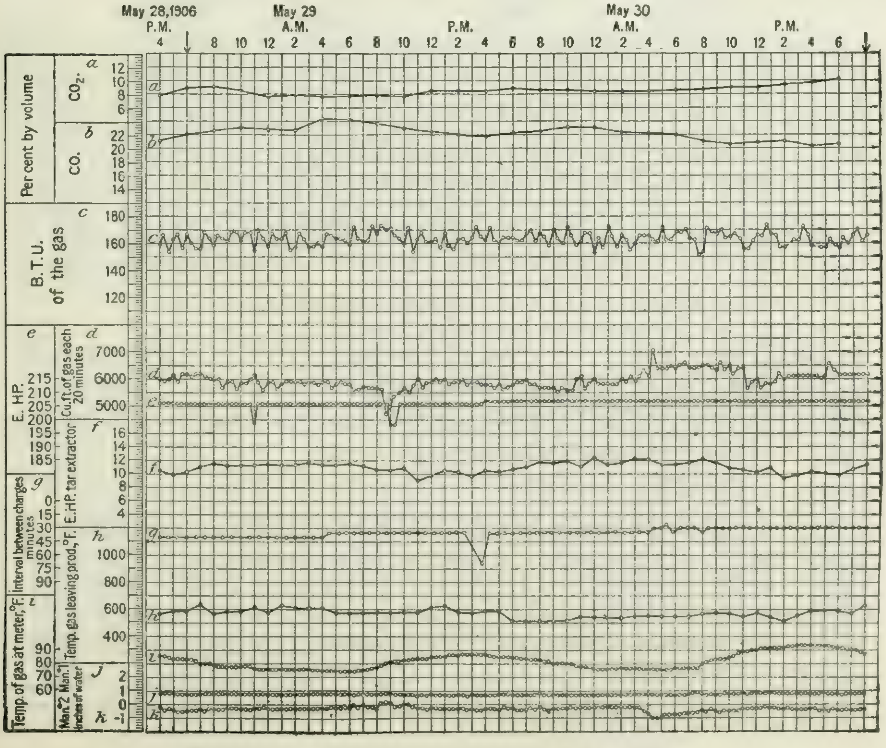
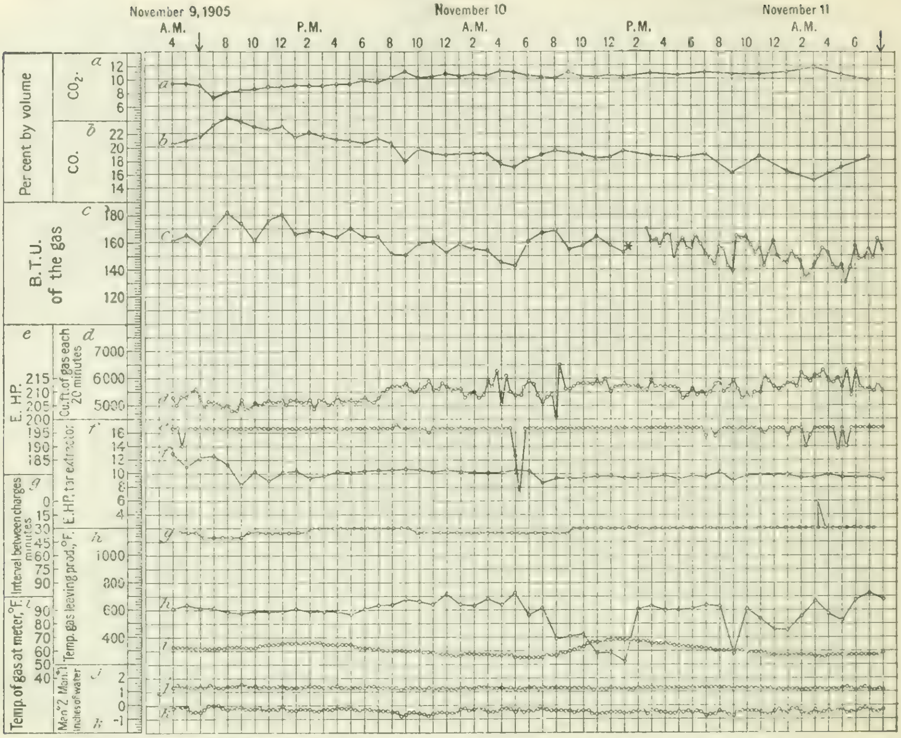


FIGURE 173.—Graphic log sheet, test No. 118, Utah No. 1 coal.



* Calculated B.T.U. used up to 1 P.M. November 10

FIGURE 174.—Graphic log sheet, test No. 77, Virginia No. 1 coal.

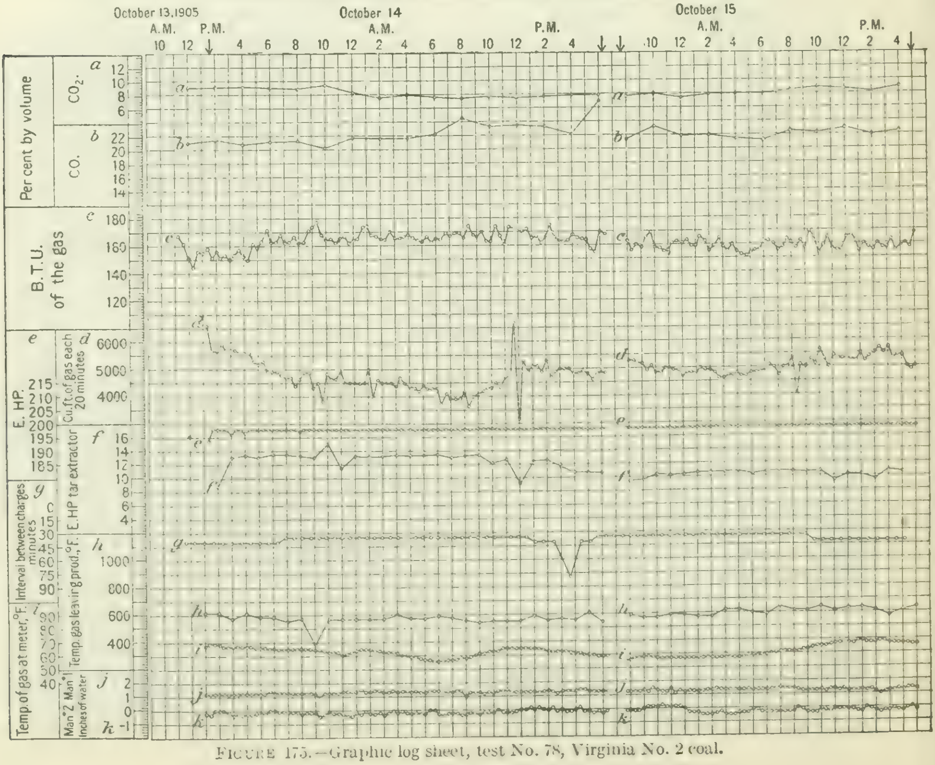
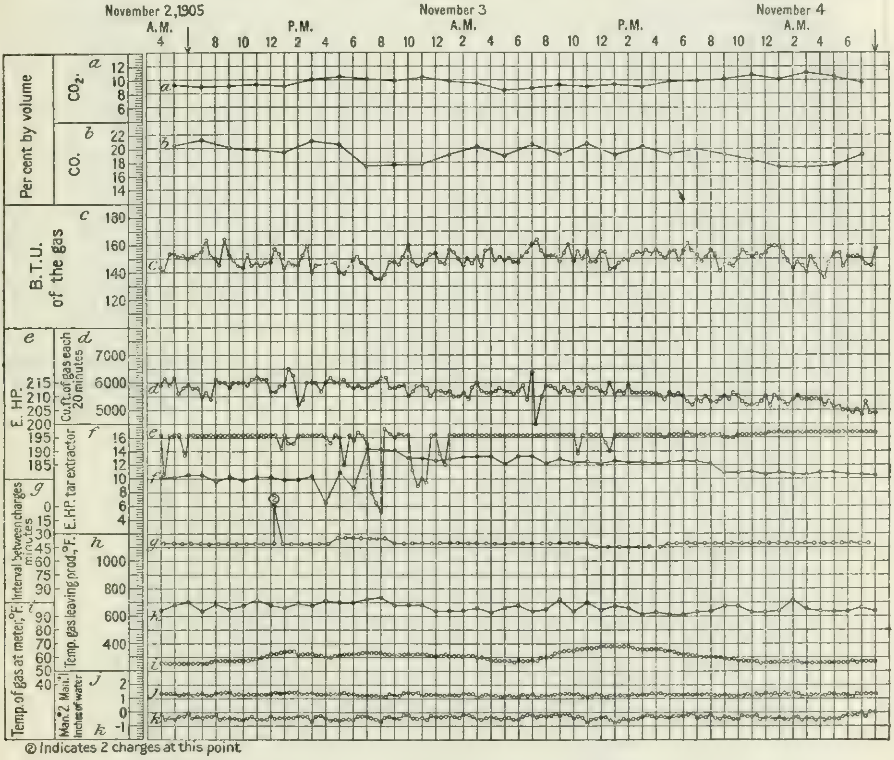


FIGURE 175.—Graphic log sheet, test No. 78, Virginia No. 2 coal.

Tennessee Nos. 8A and 8B, test 119.—The fuel used in this test was the same as that used in test 116. It behaved well and made a gas that was of uniformly good quality and had an average heat value of 158 B. t. u. per cubic foot. Full load was easily carried. After 24 hours the test was abruptly brought to a close by the breaking of water connections. Graphic log is given on page 201.

Tennessee Nos. 8A and 8B, test 119A.—This test was conducted on the same coal and under the same conditions as test 119. In fact, it was a continuation of that test after the broken water connections had been replaced. The coal continued to work well in the producer and yielded a gas with an average heat value of about 145 B. t. u. per cubic foot. The run lasted 14 hours. Graphic log is given on page 202.



② Indicates 2 charges at this point

FIGURE 176.—Graphic log sheet, test No. 75, Virginia No. 3 coal.

TEXAS.

Texas No. 1, test 11.—Texas No. 1 was a brown lignite. The gas from it was of higher heat value than that obtained from ordinary soft coal. The lignite was more difficult to handle in the producer than bituminous coal, but by frequent poking and by supplying the right amount of air the fuel bed was kept in good condition, and at the

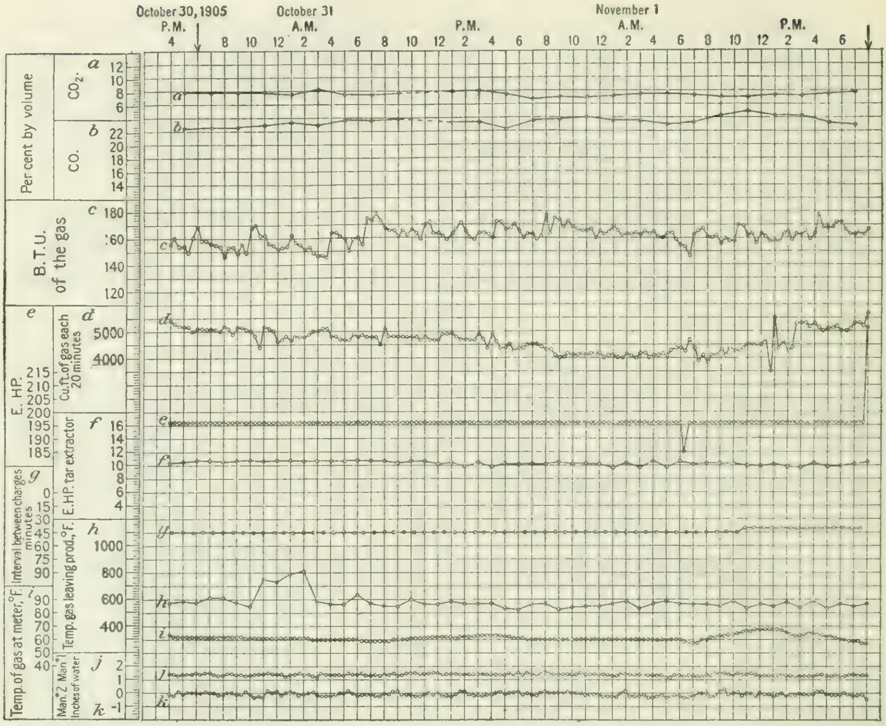


FIGURE 177.—Graphic log sheet, test No. 74, Virginia No. 4 coal.

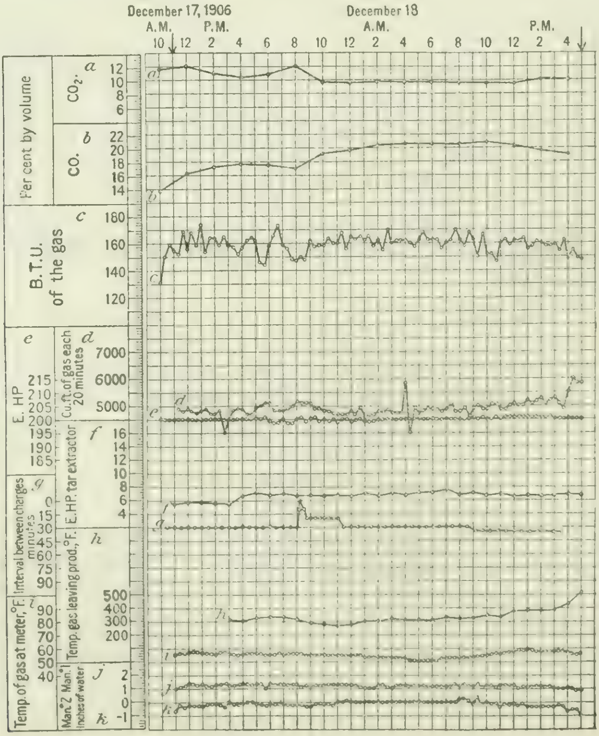


FIGURE 178.—Graphic log sheet, test No. 154, Virginia No. 5A coal.

end of the 30-hour run the clinkers in the bed could be broken up, requiring the removal of only a small amount of ash before beginning a new test. The lignite yielded a large amount (150 gallons) of yellow, sticky tar. As a producer fuel it was better than many grades of bituminous coal. Graphic log is given on page 203.

Texas No. 2, test 18.—Texas No. 2 was a brown lignite that gave highly satisfactory results in the producer. It yielded a rich gas which was rather too variable in composition to give best results in the engine. It is an excellent producer fuel. Sixty gallons of yellow tar resulted from this run. Graphic log is given on page 203.

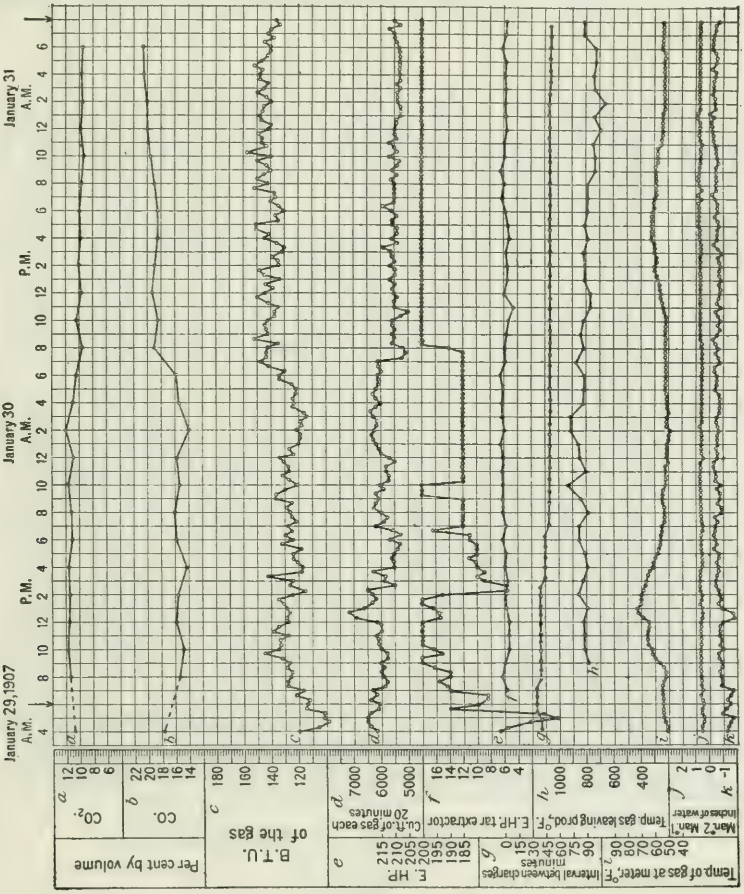
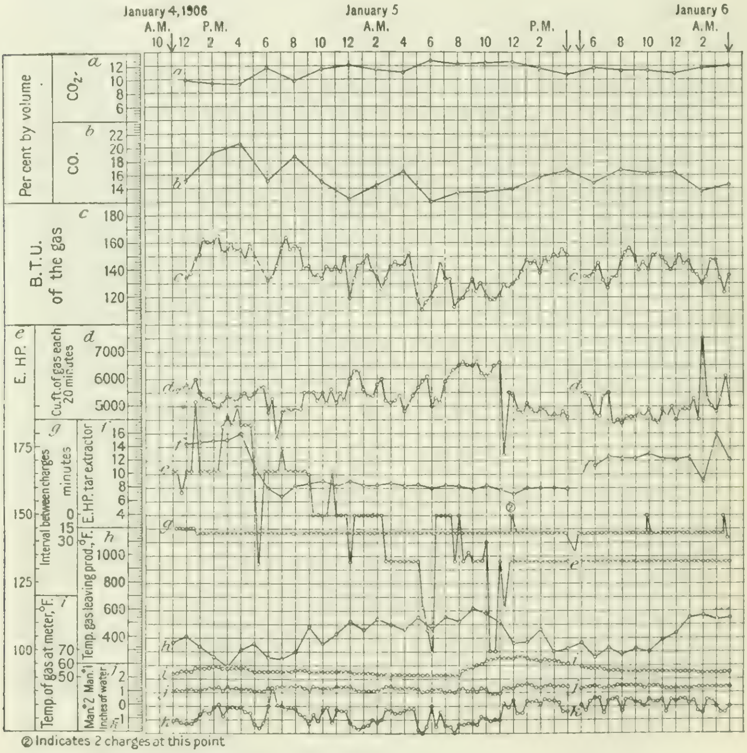


FIGURE 179.—Graphic log sheet, test No. 160, Virginia No. 6 coal.

Texas No. 3, test 93.—This fuel was a brown lignite. In many of the lumps were white streaks of what appeared to be clay. The fuel worked satisfactorily and was easily handled. The heat value of the gas was high and unusually uniform, averaging 172 B. t. u. per cubic foot. Full load was easily maintained throughout the entire run of

50 hours. No steaming test was made and the apparent evaporation determined for Texas No. 4 was used in the calculations. Graphic log is given on page 204.

Texas No. 4, test 92.—Texas No. 4 was a typical brown lignite, and was delivered to the producer platform crushed to egg size. It worked very satisfactorily. The heat value of the gas was nearly uniform and averaged 156 B. t. u. per cubic foot. The test was run for the full 50 hours, with approximately full load. Graphic log is given on page 205.



② Indicates 2 charges at this point

FIGURE 180.—Graphic log sheet, test No. 90, Washington No. 1A coal.

UTAH.

Utah No. 1, test 118.—Utah No. 1, a seemingly high-grade coal, gave satisfactory results. It worked well and showed no signs of clinkering. The gas was fairly uniform in composition and had an average heat value of 181 B. t. u. per cubic foot. The test lasted 50 hours, with a steady full load easily maintained. As there was no steaming test on this coal the apparent evaporation was calculated as explained in the footnote on page 123. Graphic log is given on page 205.

VIRGINIA.

Virginia No. 1, test 77.—Virginia No. 1, a good run-of-mine coal, gave a gas of fairly uniform composition and an average heat value of 164 B. t. u. per cubic foot. The test lasted 50 hours, with full load. Graphic log is given on page 206.

Virginia No. 2, test 78.—Virginia No. 2 was an excellent producer fuel. During the 50-hour run with full load, the producer was charged uniformly. The average heat value of the gas was 169 B. t. u. per cubic foot. Graphic log is given on page 206.

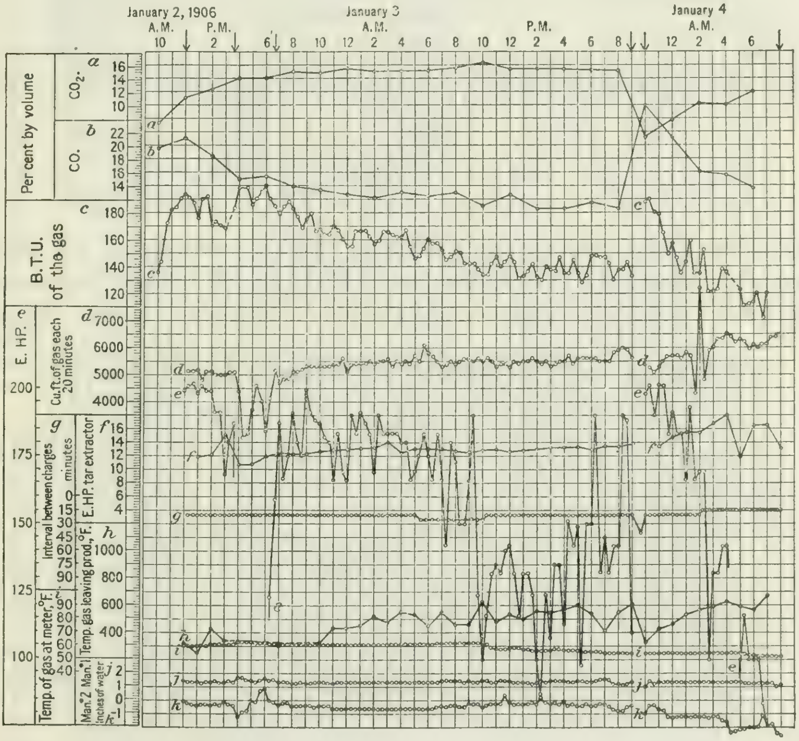


FIGURE 181.—Graphic log sheet, test No. 89, Washington No. 1B coal.

Virginia No. 3, test 75.—Virginia No. 3 coal in lump form proved well adapted for gas-producer use. The fuel bed gave no trouble. The gas from this coal, as from other coals of approximately the same composition, was rich in hydrogen, and accordingly had the high average heat value of 156 B. t. u. per cubic foot. The test lasted 50 hours, with full load. Graphic log is given on page 207.

Virginia No. 4, test 74.—Virginia No. 4 proved an excellent producer fuel, making gas of fairly uniform quality and having an average heat value of 167 B. t. u. per cubic foot. The fuel bed required little poking and the standard 50-hour test was made with ease. Graphic log is given on page 208.

Virginia No. 5A, test 154.—Virginia No. 5A, a pea-size semianthracite coal, worked well and made a rich gas of uniform quality. After running about 12 hours, however, the coal began to clinker and an excessive blast pressure was required. Extra poking gave no relief, but after grinding down the ashes the fuel bed fell several inches and the blast pressure became normal at once. The heat value of the gas did not decrease, as was expected, but rose a little. During the remainder of the test the fuel bed remained in excellent condition. The heat value of the gas averaged 161 B. t. u. per cubic foot for the

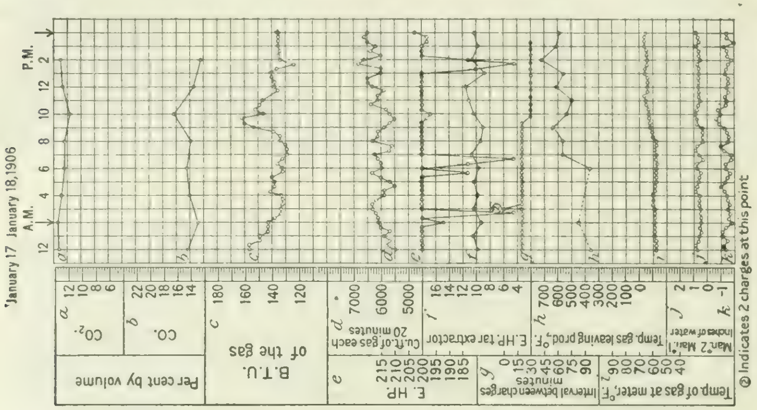


FIGURE 182.—Graphic log sheet, test No. 94, Washington No. 1B coal.

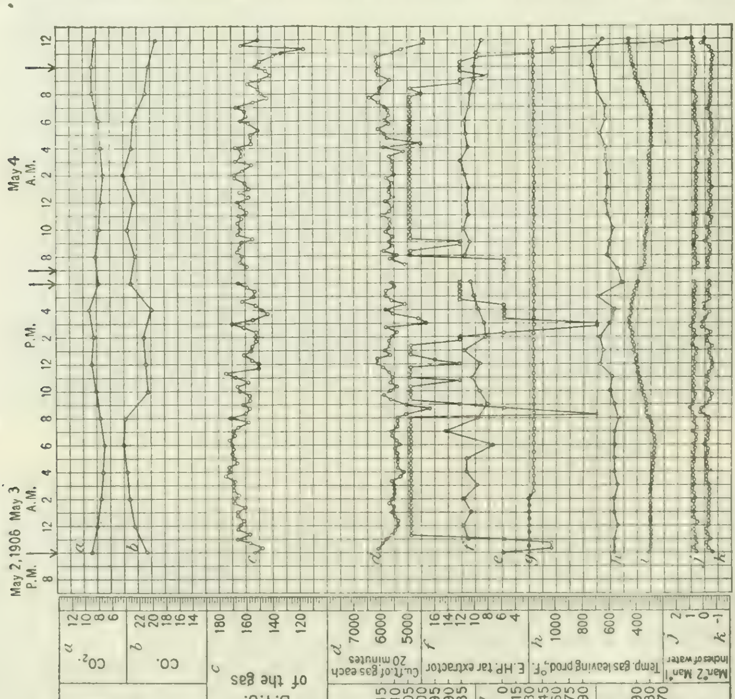


FIGURE 183.—Graphic log sheet, test No. 112, Washington No. 2 coal.

run of 30 hours, with a steady full load. Graphic log is given on page 208.

Virginia No. 6, test 160.—Virginia No. 6, when delivered on the producer platform, was mostly slack. During the first part of the test the formation of channels at the sides of the producer gave some trouble. With only partial load and by careful poking the fuel bed was worked into good condition, after which full load was carried. The heat value of the gas was variable at first, but after the fuel bed was in good condition it became more uniform and averaged 138 B. t. u. per cubic foot for the run. Graphic log is given on page 209.

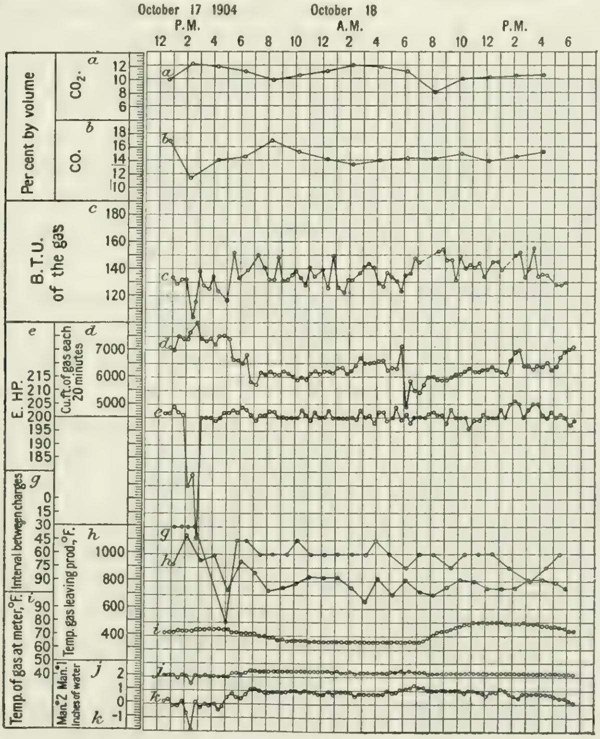


FIGURE 184.—Graphic log sheet, test No. 3, West Virginia No. 1 coal.

WASHINGTON.

Washington No. 1A, test 90.—Washington No. 1A, a mixture of pea and slack, was a subbituminous coal which had been washed. The gas fluctuated in heat value, but by charging fuel every 20 minutes, occasionally making a double charge, and by persistently poking the fuel bed, two-thirds full load was maintained. Ash accumulated rapidly, the fuel bed gradually increased in thickness, and some trouble was experienced by burning of the gas at the top of the fuel bed. After running 29 hours the entire load was taken from the engine and the bottom of the producer was opened for the purpose of removing the ash. In about 45 minutes the test was resumed with two-thirds full load. The fuel bed continued to increase in thickness and it was difficult to keep it in good condition. The run was brought to a close after 40 hours. As there was no steaming test on this coal, the apparent evaporation was assumed to be the same as that for Washington No. 1B. Graphic log is given on page 210.

Washington No. 1B, test 89.—Washington No. 1B was a subbituminous coal high in volatile matter. It was delivered to the producer platform in run-of-mine form, but a large proportion of it had become slack, and to this may be attributed the difficulty experienced in producing a gas of uniform quality. During the first few hours of the test the heat value of the gas was high (175 to 200 B. t. u. per cubic foot), but it soon began to diminish, and though fluctuating considerably, decreased to about 100 B. t. u. per cubic foot at the end of the run. After 30 hours' run the new water-seal valve became filled with tar and soot to such an extent that it interfered with the flow of gas, and the pressure at the top of the producer became excessive. A change to the other producer relieved the difficulty, and for the next 4 hours the heat value of the gas was high, as in the beginning of the test, but it soon began to diminish rapidly and after a 40-hour run the test was brought to a close. Graphic log is given on page 211.

Washington No. 1B, test 94.—A small quantity of the coal remaining from test 89 was used for a short but comparatively satisfactory test. The gas was of moderately uniform quality and had an average heat value of 144 B. t. u. per cubic foot. Full load was carried. Graphic log is given on page 212.

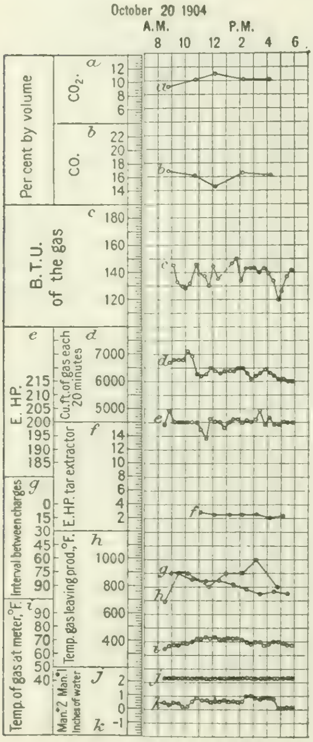


FIGURE 185.—Graphic log sheet, test No.4, West Virginia No. 4 coal.

Washington No. 2, test 112.—Washington No. 2 coal worked satisfactorily. It gave a rich gas of uniform quality except during the last few hours of the test, when the heat value of the gas decreased slightly. During the run of 35 hours the average heat value of the gas was 169 B. t. u. per cubic foot. Fluctuations in the water supply caused variations in the engine load. Graphic log is given on page 212.

WEST VIRGINIA.

West Virginia No. 1, test 3.—At the beginning of this test the fuel bed was in poor condition, as it had not been given the proper attention, but it was brought into good working order in 6 hours and full load was carried during the remainder of the run. The gas varied in composition, due to fluctuations in the temperature and thickness of the fuel bed. Graphic log is given on page 213.

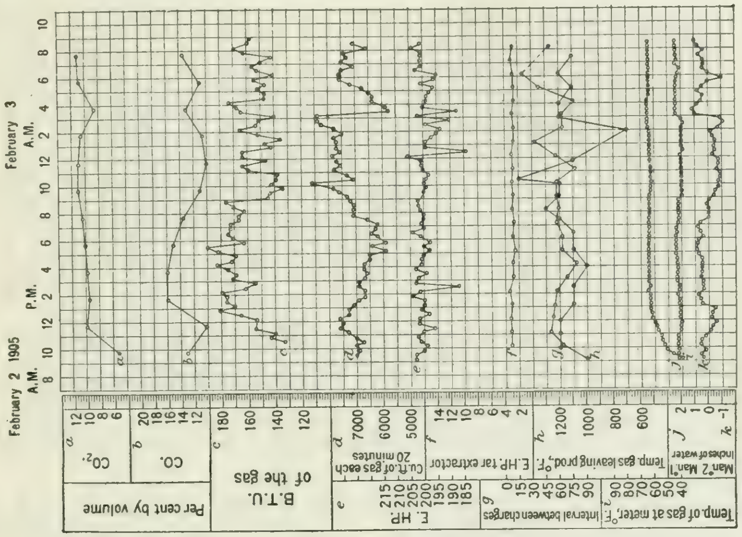


FIGURE 186.—Graphic log sheet, test No. 23, West Virginia No. 7 coal.

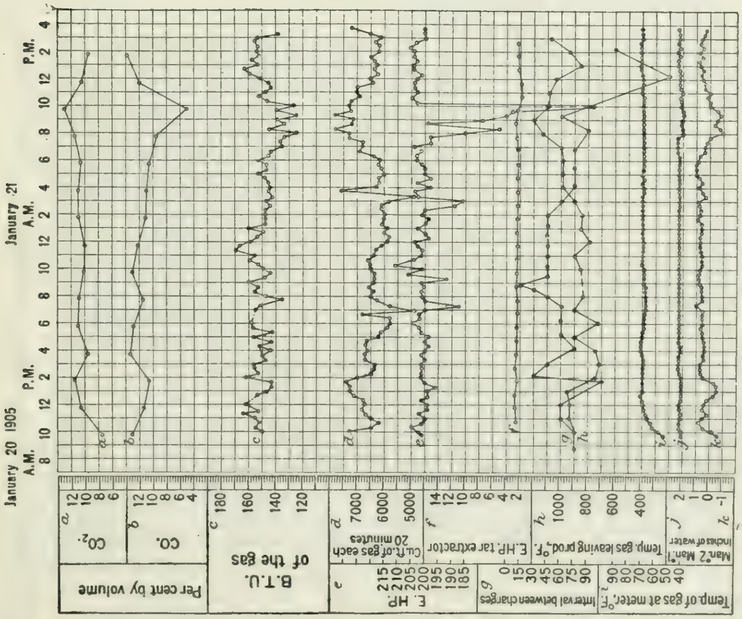


FIGURE 187.—Graphic log sheet, test No. 19, West Virginia No. 8 coal.

West Virginia No. 4, test 4.—This coal was soft and friable, and as charged consisted mainly of slack. It coked freely at the top of the fuel bed and gave no indications of clinkering. Owing to the small supply of coal the test was necessarily of short duration, but enough was done to show that it was an excellent gas-producer fuel. Graphic log is given on page 214.

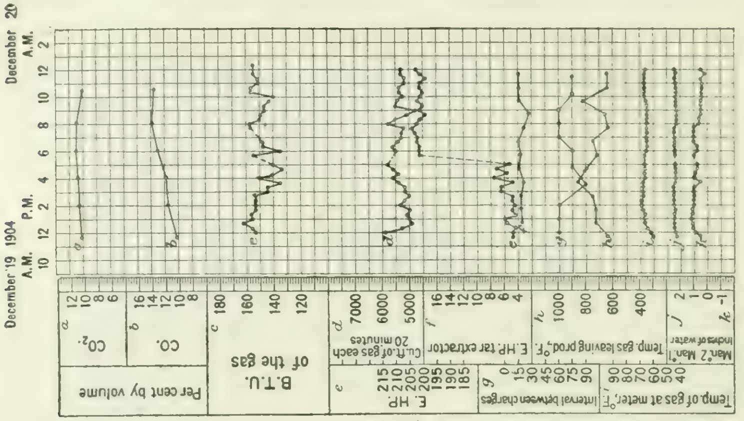


FIGURE 188.—Graphic log sheet, test Nos. 17A and 17B, West Virginia No. 9 coal.

West Virginia No. 7, test 23.—This fuel was of high grade and it proved an excellent producer coal, yielding a rich gas of uniform quality. Graphic log is given on page 215.

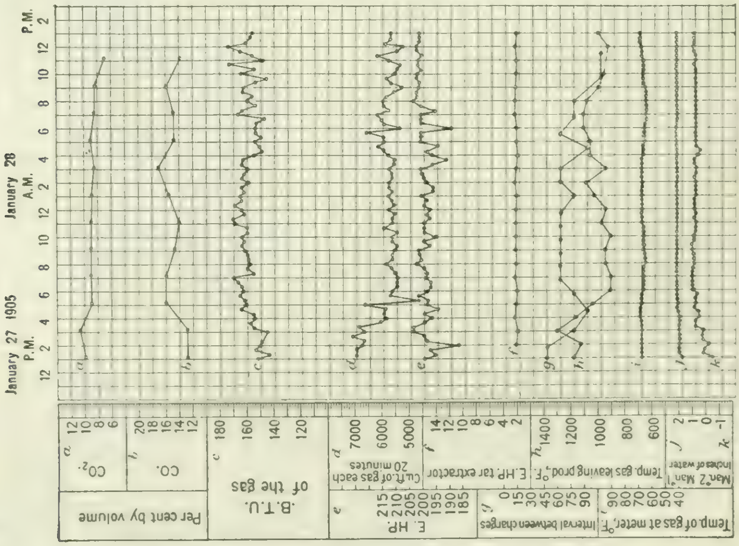


FIGURE 189.—Graphic log sheet, test No. 21, West Virginia No. 9 coal.

West Virginia No. 8, test 19.—This was a good producer coal, although it was difficult to keep the fuel bed from becoming excessively hot on account of the large amount of fine coal in this particular sample. The heat value of the gas was high and fairly uniform. About 75 gallons of black tar were extracted. Graphic log is given on page 215.

West Virginia No. 9, tests 17A and 17B.—West Virginia No. 9 was a high-grade bituminous coal. It burned well and was easily handled in the producer, yielding a gas of uniformly good quality. It made a good producer fuel. One hundred and twenty gallons of black tar were extracted. Graphic log is given on page 216.

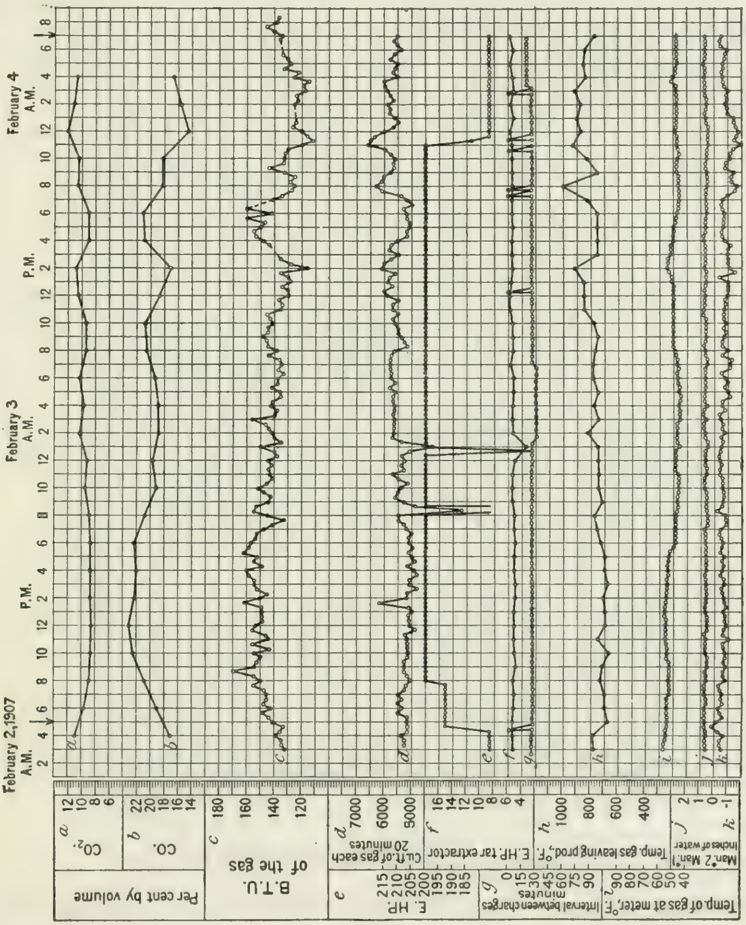


FIGURE 190.—Graphic log sheet, test No. 161, West Virginia No. 11B coal.

West Virginia No. 9, test 21.—This test was the second run on West Virginia No. 9. The coal worked satisfactorily in the producer and gave good results. Fifty gallons of black tar were extracted. Graphic log is given on page 216.

West Virginia No. 11B, test 161.—West Virginia No. 11B was a bone coal considered of little or no value for steam-boiler work, and heretofore untried in the producer. As delivered on the producer platform this coal contained lumps up to 8 or 10 inches in diameter and as the coal crusher was not available these lumps were broken with a hammer. Some rocklike pieces gave off sparks when struck with the hammer; other lumps contained much good coal. All lumps, if not too large, burned entirely through. The fuel had no tendency to clinker or cake, and worked exceedingly well, requiring little poking. The high percentage of ash (about 44 per cent) caused the ash bed to increase in thickness very rapidly, and as this fact was not properly appreciated the ash bed was too high much of the time for best results. Lumps much larger than desirable were charged. These large lumps, high in ash, did not burn entirely through, the ash layer formed interfering with combustion. Because of the unpromising appearance of the coal little was expected of it, and the test was started with only part load, but after several hours' run the results warranted full load. After maintaining full load for 39 hours the accumulation of ash in the producer caused trouble, and the heat value of the gas diminished, necessitating a reduction to about 90 per cent of full load. By grinding down the ash bed and by using greater care in breaking the lumps the heat value of the gas was increased so that at the end of the test full load was carried. The calculations for the test are

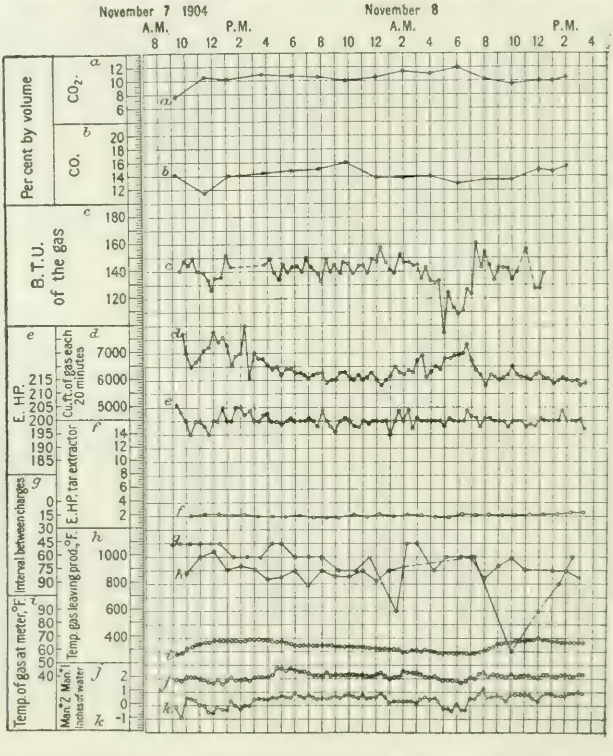


FIGURE 191.—Graphic log sheet, test No. 8, West Virginia No. 12 coal.

based on the 50-hour period commencing when full load was put on. During this period the average heat value of the gas was 144 B. t. u. per cubic foot and the average load was 97 per cent of full load. Graphic log is given on page 217.

West Virginia No. 12, test 8.—West Virginia No. 12 coal was of good quality and worked satisfactorily in the producer. It was soft and friable, and in being crushed much of it was reduced to a fine powder, which gave trouble in the scrubber. It yielded about 50 gallons of tar. It may be considered a good producer coal. Graphic log is given on page 218.

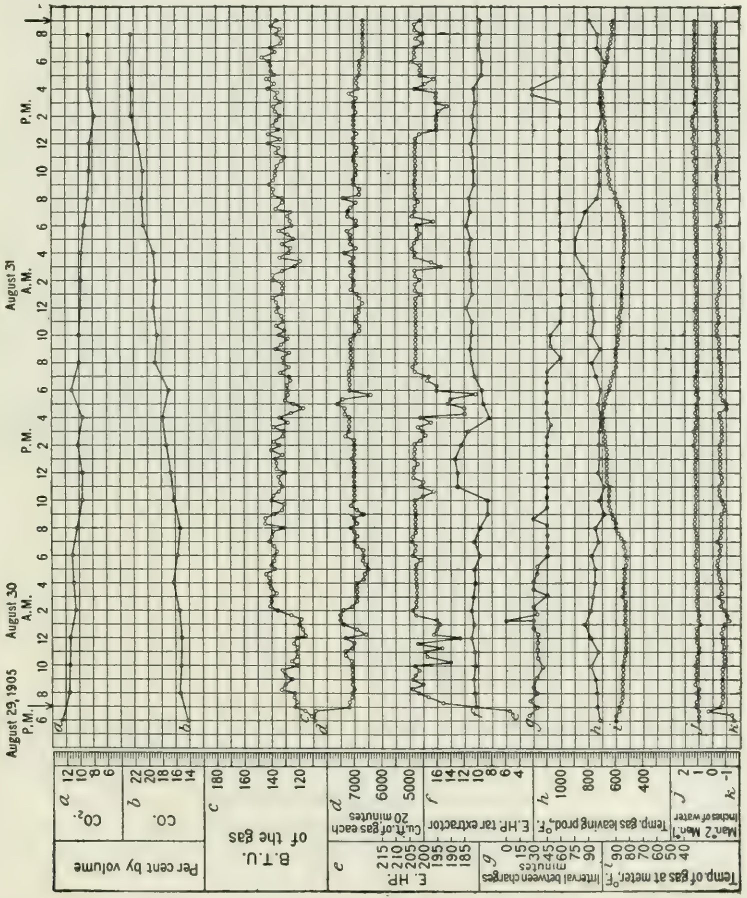


FIGURE 192.—Graphic log sheet, test No. 56, West Virginia No. 13 coal.

West Virginia No. 13, test 56.—West Virginia No. 13 coal in run-of-mine form proved an excellent producer fuel. A gas of uniform quality was generated, having an average heat value of 139 B. t. u. per cubic foot, and there was no difficulty whatever in completing the 50-hour test with full load. Graphic log is given on page 219.

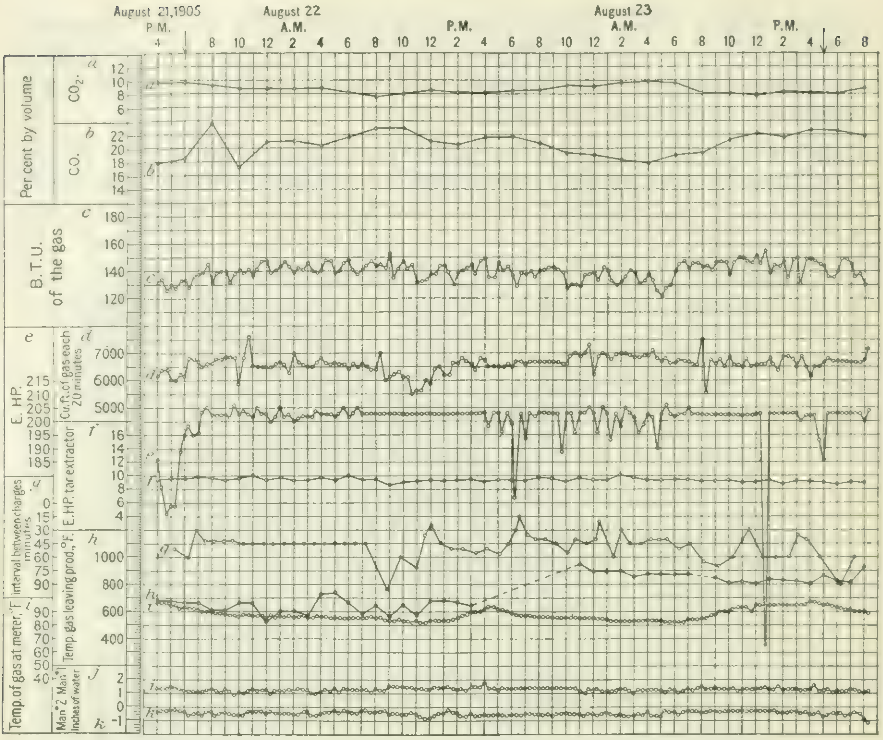
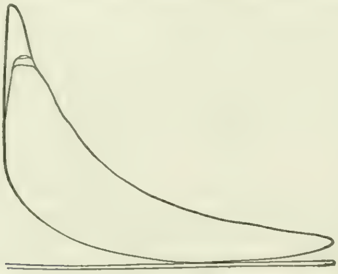
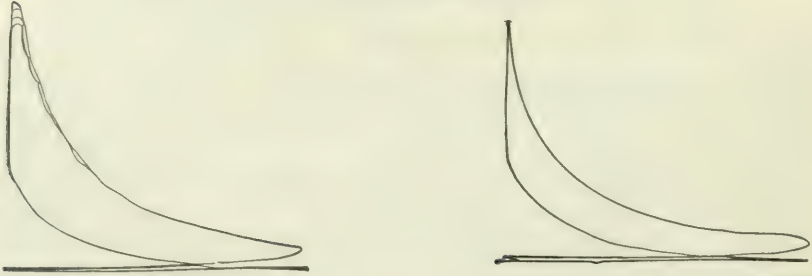


FIGURE 193.—Graphic log sheet, test No. 54, West Virginia No. 14 coal.



Center cylinder. M. E. P., 80; Max., 304; Rel., 32; I. H. P., 119.5.



Right cylinder. M. E. P., 61; Max., 294; Rel., 27; I. H. P., 91.3.

Left cylinder. M. E. P., 44; Max., 292; Rel., 27; I. H. P., 65.8.

FIGURE 194.—Indicator cards, test No. 54, West Virginia No. 14 coal. Scale of spring, 80; revolutions per minute, 189.8.

West Virginia No. 14, test 54.—West Virginia No. 14 coal gave good results. The gas was of uniform quality and had an average heat value of 147 B. t. u. per cubic foot. Graphic log is given on page 220.

West Virginia No. 16A, test 86.—As West Virginia No. 16A showed a tendency to heat excessively in the fuel bed, cold air was used in the blast. The gas had an average heat value of 156 B. t. u. per cubic foot, but was not as uniform in quality as the gas from West Virginia No. 13 or West Virginia No. 14. The test lasted 50 hours, with full load. Graphic log is given on page 221.

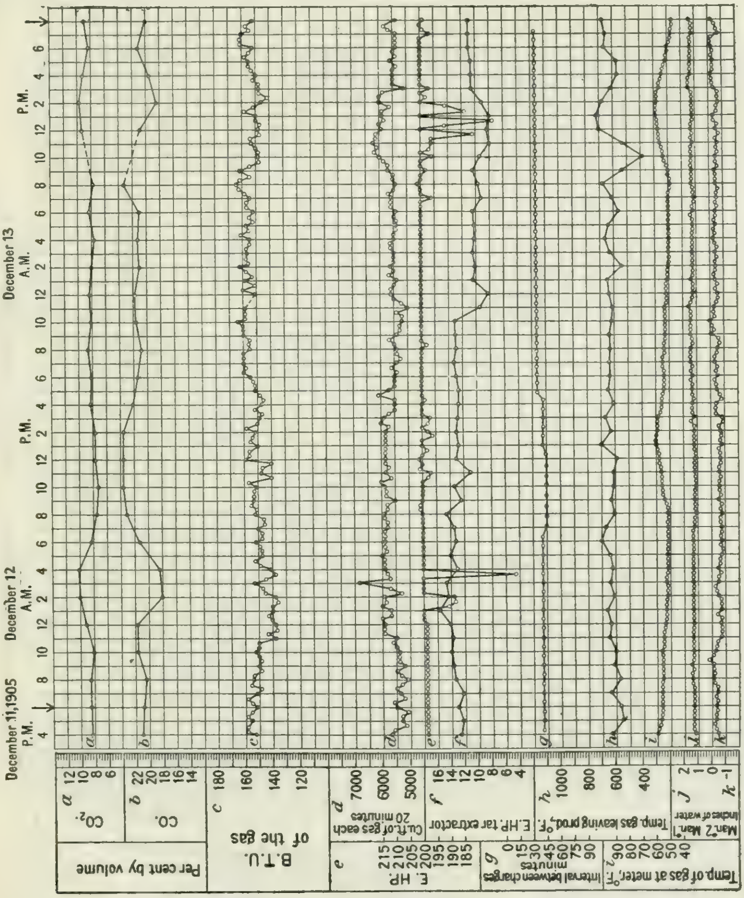


FIGURE 195.—Graphic log sheet, test No. 86, West Virginia No. 16A coal.

West Virginia No. 18, test 80.—West Virginia No. 18 was a first-class producer coal. No trouble was experienced in handling the fuel bed, and a gas of uniform quality with an average heat value of 159 B. t. u. per cubic foot was produced. The standard full-load 50-hour test was made. Graphic log is given on page 222.

West Virginia No. 20, test 82.—Good gas was made from West Virginia No. 20 coal, although the sample tested was largely dust. On account of cold weather preheated air was used in the blast. The gas was fairly uniform in quality and had an average heat value of 156 B. t. u. per cubic foot for the 50-hour test. Graphic log is given on page 223.

West Virginia No. 24, test 162.—West Virginia No. 24 was a bone coal. But unlike the coal used in test 161, West Virginia No. 11B, it was almost entirely slack. The fuel bed required careful watching and gave some trouble from blowholes. The heat value of the gas fluctuated a great deal and at times was so low that the gas would not burn in the calorimeter. The average load for the 50-hour test was about three-fourths of full load. The average heat value of the gas was 106 B. t. u. per cubic foot. No steaming test was run on this coal, and as the formula for calculating the apparent evaporation was inapplicable, no equivalent values were determined. Graphic log is given on page 224.

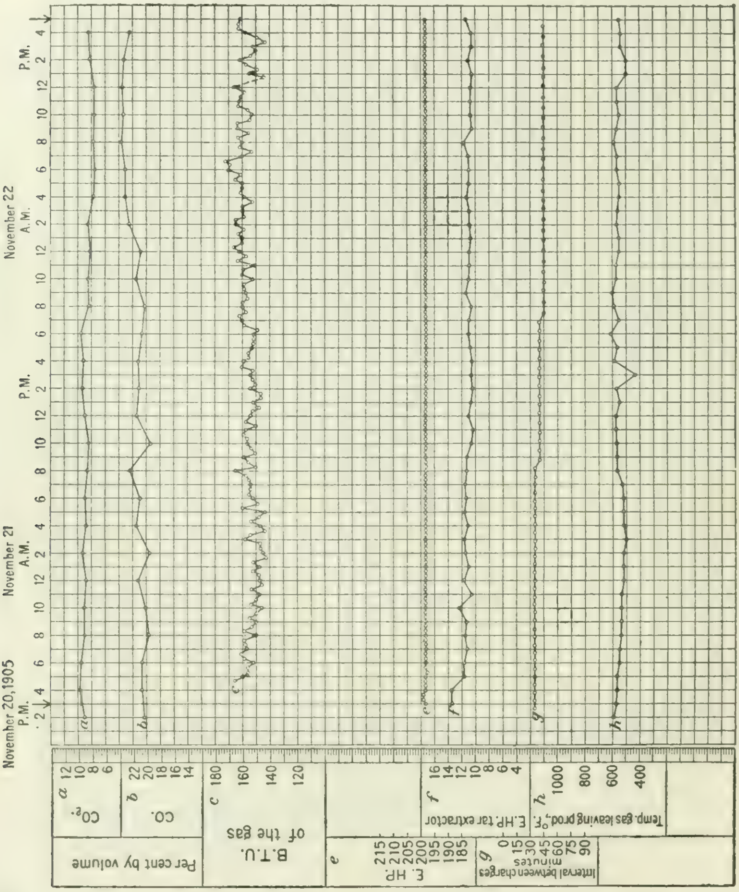


FIGURE 196.—Graphic log sheet, test No. 80, West Virginia No. 18 coal.

West Virginia No. 25, test 156.—West Virginia No. 25, a firm, hard coal containing little or no slack, worked exceptionally well in the producer. It made a gas of uniform quality with less than the average percentage of carbon dioxide, and with an average heat value of 172 B. t. u. per cubic foot. Throughout the test the blast pressure was unusually low. This coal gave much tar of a dark-brown color. The test lasted 50 hours with full load. As there was no steaming test on this coal the apparent evaporation was calculated as explained in the footnote on page 123. Graphic log is given on page 225.

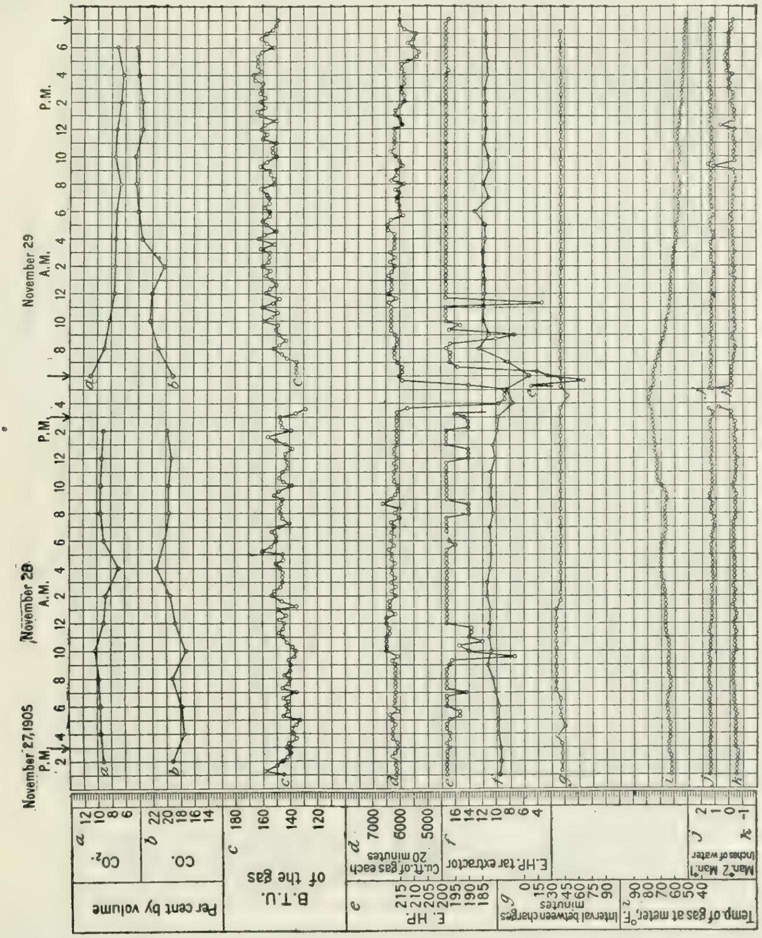


FIGURE 197.—Graphic log sheet, test No. 82, West Virginia No. 20 coal.

WYOMING.

Wyoming No. 2, test 16.—Wyoming No. 2 was a bituminous coal. It burned without clinkering, leaving a large amount of white ash similar to that obtained from wood. The gas was not uniform in quality on account of the difficulty experienced in keeping the fuel bed in good condition. Sixty gallons of yellow tar were produced. Graphic log is given on page 226.

Wyoming No. 2B, test 62.—Wyoming No. 2B, a low-grade bituminous coal, can not be classed as a good producer fuel. It clinkered in the generator and difficulty was experienced in keeping the fuel bed free from blowholes. The gas was not of very uniform quality, but had an average heat value of 147 B. t. u. per cubic foot. The test lasted 49 hours with a load which fluctuated considerably. Graphic log is given on page 227.

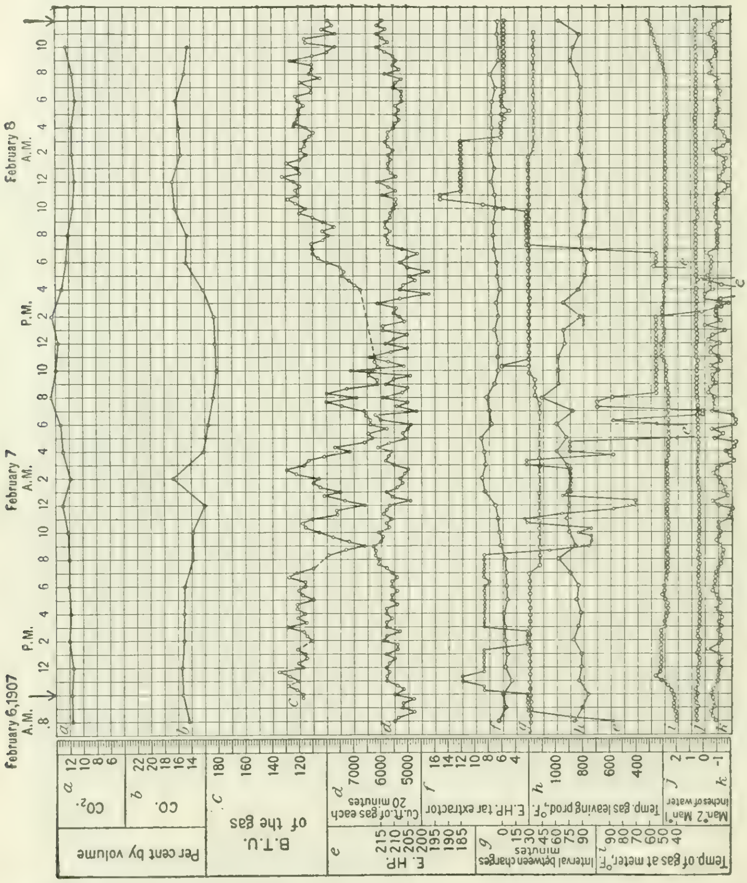


FIGURE 198.—Graphic log sheet, test No. 162, West Virginia No. 24 coal.

Wyoming No. 3, test 69.—Wyoming No. 3 coal was somewhat difficult to handle in the producer, although it made a gas of fairly uniform quality and having an average heat value of 161 B. t. u. per cubic foot. The fuel bed required frequent poking to prevent the formation of blowholes. Graphic log is given on page 228.

Wyoming No. 4, test 123.—Wyoming No. 4 coal worked well in the producer, making a gas with an average heat value of 152 B. t. u.

per cubic foot and of generally uniform quality. At the beginning of the test the fuel bed was rather thin, and after about 10 hours' run showed a tendency to burn through and form blowholes. Approximately full load was carried during the 50-hour test. Graphic log is given on page 229.

Wyoming No. 5, test 114.—Wyoming No. 5 coal worked unusually well in the producer, making a gas with an average heat value of 168 B. t. u. per cubic foot. After running 35 hours the gas meter was by-passed and was not used again during the test. A few hours before the end of the run, trouble with an igniter on the engine caused a shutdown of about an hour. As there was no steaming test made on this coal the apparent evaporation was calculated as explained in the footnote on page 123. Graphic log is given on page 230.

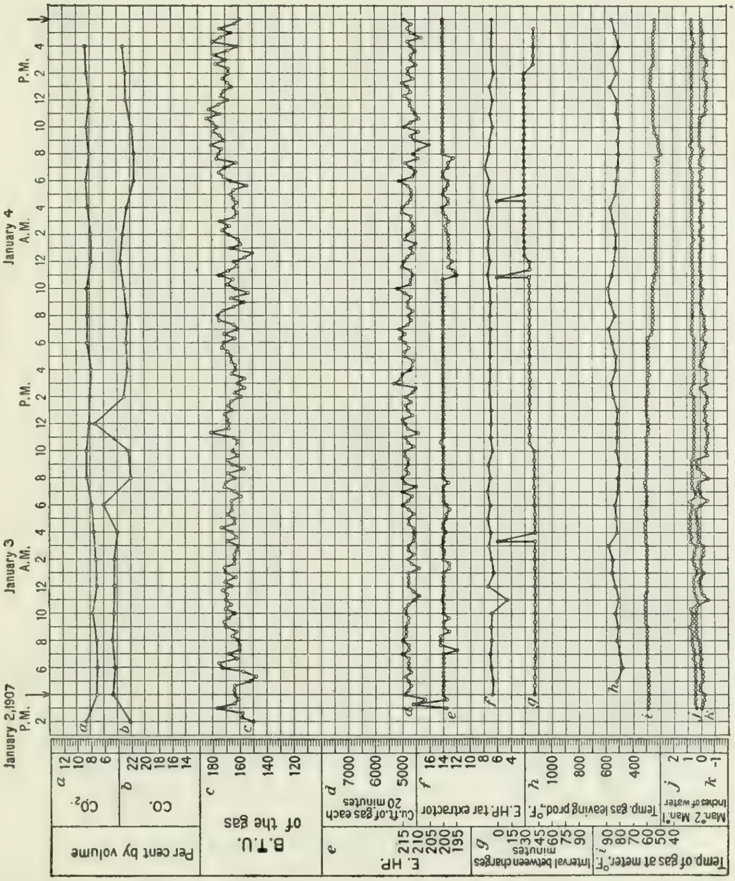


FIGURE 199.—Graphic log sheet, test No. 156, West Virginia No. 25 coal.

Wyoming No. 6, test 124.—Wyoming No. 6, a subbituminous coal, gave satisfactory results in the producer. It was easy to handle and made a gas with an average heat value of 172 B. t. u. per cubic foot. During the 50-hour test full load was easily carried. Graphic log is given on page 231.

MISCELLANEOUS.

Miscellaneous coke, test 151.—A firm, hard, light-colored coke was charged, as received, in 3-inch and 4-inch lumps on a fuel bed 5 to 5½ feet thick. During the first part of the test the gas was uniform in quality and had a heat value of about 125 B. t. u. per cubic foot. Toward the end of the run the heat value decreased, making the average for the test 121 B. t. u. per cubic foot. The fuel bed was rather hot and the temperature of the gas leaving the producer gradually increased during the test, becoming as high as 1,004° F., though the average temperature was 883° F. A steady full load was carried throughout the 41-hour test. Graphic log is given on page 232.

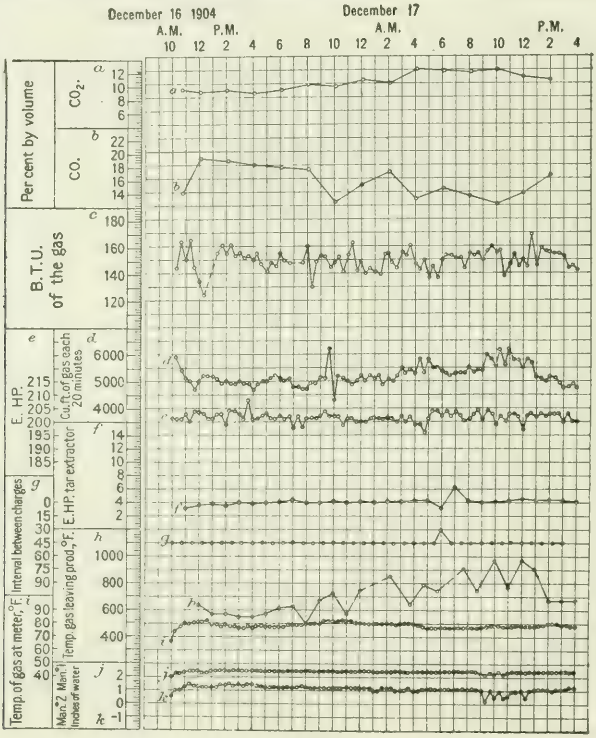


FIGURE 200.—Graphic log sheet, test No. 16, Wyoming No. 2 coal.

Coke breeze, test 50.—The coke breeze used in this test was furnished in two grades, coarse and fine. The coarse breeze, owing to its lightness and dryness, caused considerable trouble, the fuel bed getting too hot near the generator walls The gas fluctuated widely in quality, but had an average heat value of 137 B. t. u. per cubic foot. The test lasted 30 hours. When fine breeze was charged the dust blown over by the blast so clogged the pipes that the engine stopped for want of gas. Graphic log is given on page 233.

Washery refuse, test 153.—An attempt to use washery refuse was made in test 153. This refuse contained 3½ per cent sulphur, more than 40 per cent ash, less than 30 per cent fixed carbon, and about 19 per cent volatile matter. It was charged on a good fuel bed of lignite, and while the lignite lasted a gas of fair quality was made; but as soon as the fuel bed was made up entirely of washery refuse it was difficult to generate gas at all. There was considerable slate, shale, and dirt in the refuse, which fused to such an extent that the blast had little effect except at the edges of the fuel bed. The engine was started several times on very low-grade gas and with no load, but after about 3 hours' run the engine would usually stop of its own accord.

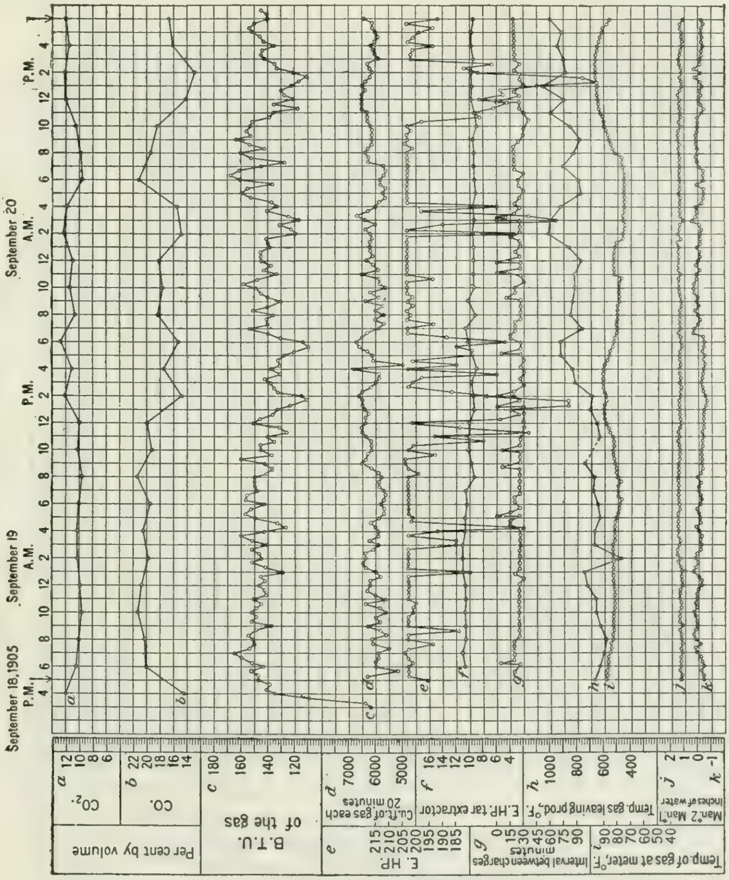


FIGURE 201.—Graphic log sheet, test No. 62, Wyoming No. 2B coal.

NORFOLK TESTS.

JAMESTOWN No. 1.

Jamestown No. 1, test 163.—The first test made after the installation of the plant at Norfolk was of short duration because of the limited water supply, but it served to try out the plant before any long runs were attempted, and, on the whole, was satisfactory. The fuel used, a Virginia run-of-mine coal, when delivered on the producer platform, was one-half to two-thirds slack. Its heat value was about 12,600 B. t. u. per pound and it contained 15 per cent of ash. Although the stokers were new men and had never had any previous experience with gas producers, they kept the fuel bed in excellent condition. The quality of the gas was fairly uniform. The engine ran satisfactorily and carried full load without difficulty.

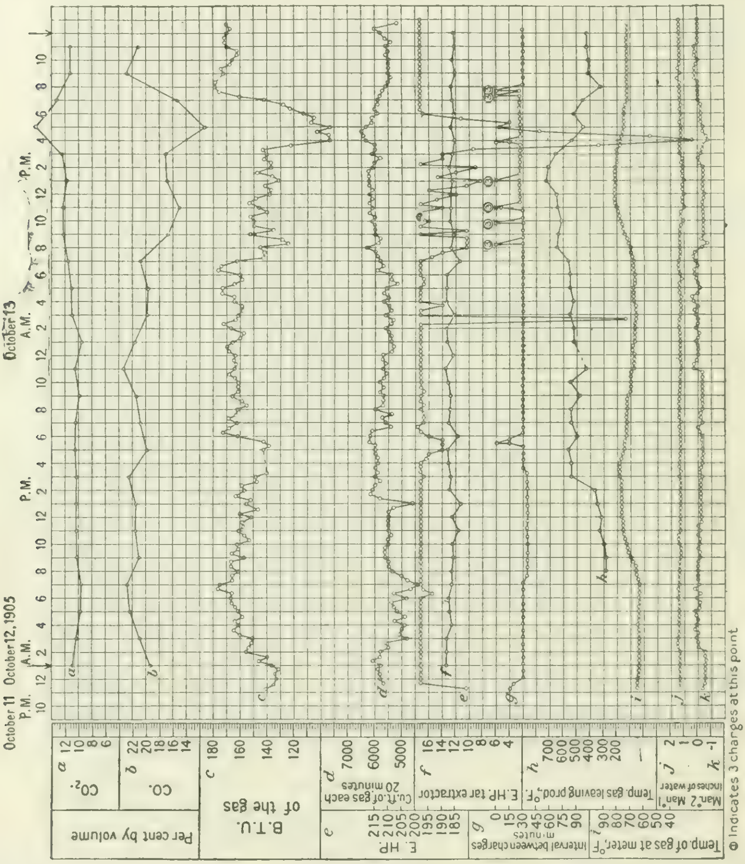


FIGURE 202.—Graphic log sheet, test No. 69, Wyoming No. 3 coal.

Water meters had not yet been installed, and consequently there is no record of the quantity of water used. The water pressure varied considerably at times, causing preignition and trouble in lubricating the engine cylinders. Owing to the unreliable water supply it was impossible to carry this test beyond 8 consecutive hours, a period so short that the results can not be regarded as accurate. Graphic log is given on page 234.

JAMESTOWN, No. 3.

Jamestown No. 3, test 164.—The fuel used during test 164 was a Pocahontas run-of-mine coal from West Virginia. For several days before the test the producer was in running condition, but there was an unavoidable delay on account of lack of water for cooling the engine cylinders. During this delay the coal, which had been charged from time to time to hold the fire, caked into a hard mass, which had to be broken up by poking when the preliminary run was commenced.

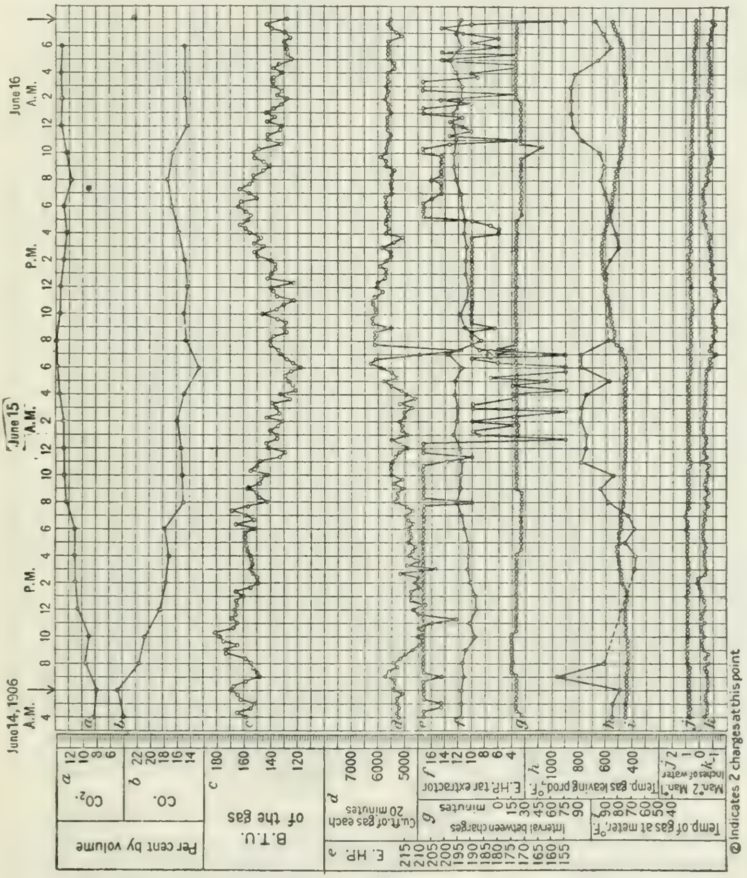


FIGURE 203.—Graphic log sheet, test No. 123, Wyoming No. 4 coal.

September 25: The engine was started for the preliminary run at 10.35 a. m. On account of a new main bearing and the fact that the crank shaft had been lined up just previous to starting, only a light load was carried during the first few hours of the run. The fuel bed, at first in rather poor condition, was brought into excellent working order after a few hours' run. Although the new main bearing in the engine heated, the load was increased gradually until at 10 p. m. the engine was carrying practically full load and was running smoothly. At 11.30 p. m. a few premature explosions took place in the right cylinder; the outlet temperature of the jacket water, while not high (125°F.), was lowered a little by increasing the quantity of jacket water and the preignition ceased. Throughout the night the producer worked well, making a gas with a heat value of about 130 B. t. u. per cubic foot. The engine ran steadily and carried full load without difficulty.

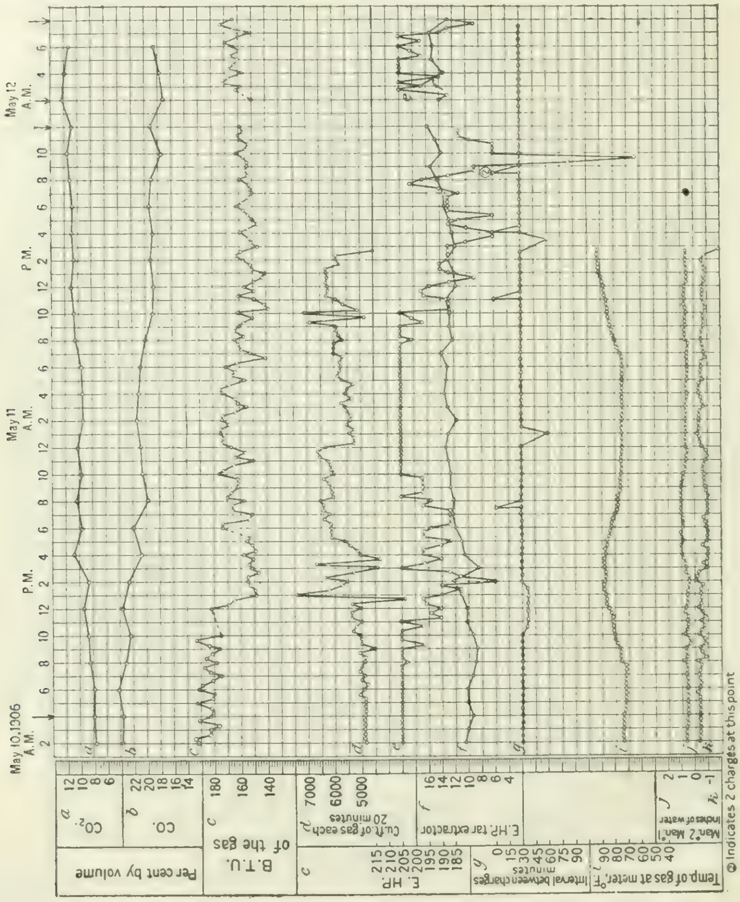


FIGURE 204.—Graphic log sheet, test No. 114. Wyoming No. 5 coal.

September 26: At 8 a. m. the preliminary run was brought to a close and the official test was begun, with the producer working satisfactorily and the engine carrying full load. Coal was charged at intervals of 1 hour. The fuel bed was in excellent condition, and the heat value of the gas was fairly uniform at about 130 B. t. u. per cubic foot. At 2 p. m. the water supply temporarily decreased, necessitating a reduction in the load for 15 minutes.

At the beginning of the evening shift[a] both the producer and the engine were working satisfactorily. At 5.30 p. m. the gas pressure at the producer began to increase owing to the collection of water in the drip well and pipe line between the tar extractor and gas holder; the drip well was at once pumped out and the pressure became normal. At 6 p. m. the engine back fired a few times, and a little later, owing to faulty ignition, the left cylinder misfired; this was soon remedied, and throughout the rest of the shift the engine ran smoothly and carried an even full load. The heat value of the gas varied only 9 B. t. u. per cubic foot during the shift.

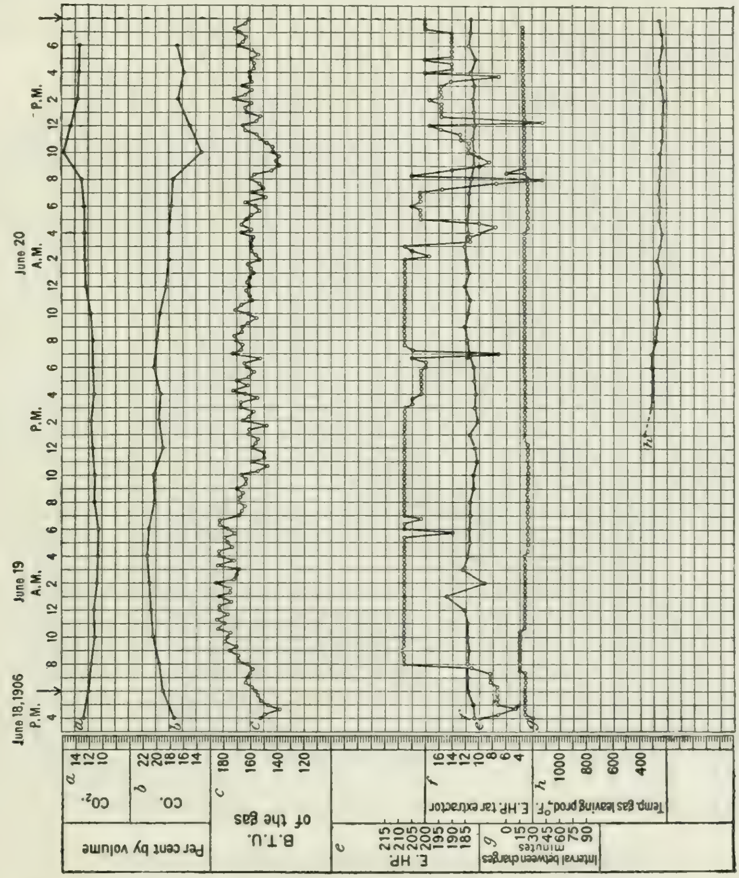


FIGURE 205.—Graphic log sheet, test No. 124, Wyoming No. 6 coal.

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[a] In this and in the succeeding tests made at Norfolk, the day was divided into three shifts, as follows: The morning shift from 12 a. m. to 8 a. m., the day shift from 8 a. m. to 4 p. m., and the evening shift from 4 p. m. to 12 p. m.

September 27: At 1.15 a. m. the engine back fired a few times and there were several premature explosions. These preignitions were stopped by the use of more jacket water. The producer was in excellent working condition, but at 2.30 a. m., as the fuel bed was getting rather low, the interval between charges was changed from 1 hour to 45 minutes. Throughout the shift the heat value of the gas varied only 10 B. t. u. and averaged 135 B. t. u. per cubic foot.

During the day shift the producer was in excellent condition, and the engine worked satisfactorily, but the load varied considerably on account of a variable motor load.

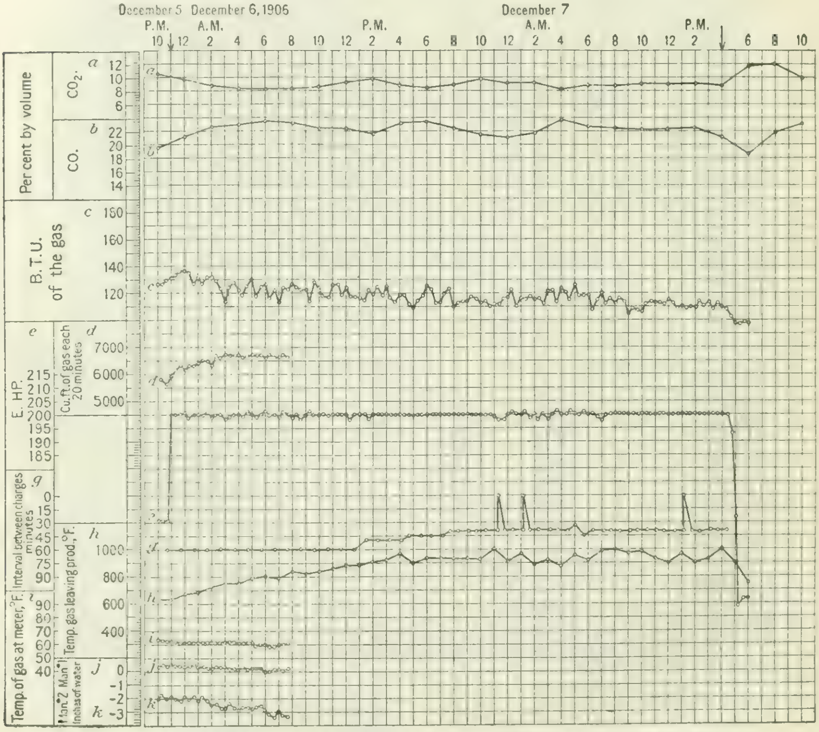
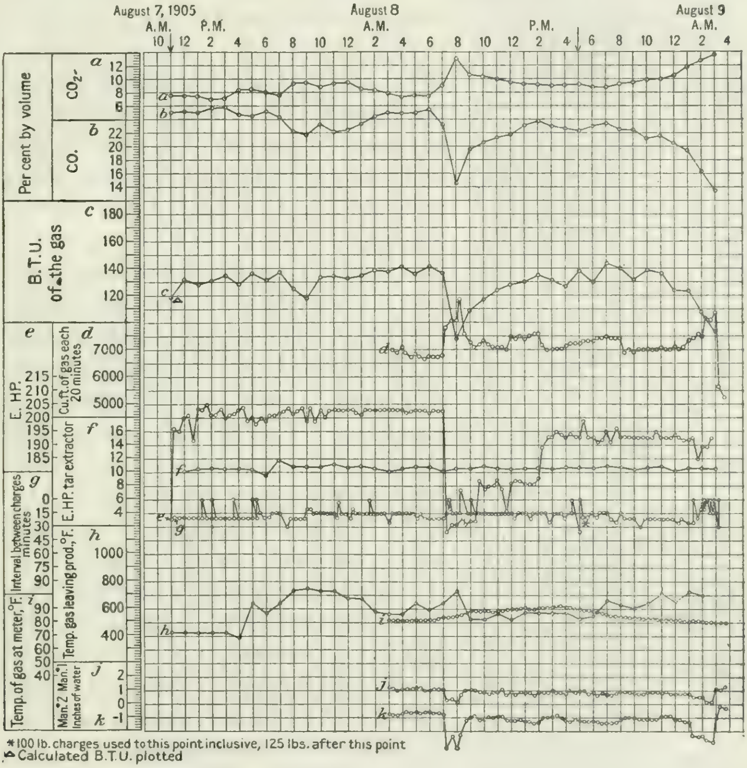


FIGURE 206.—Graphic log sheet, test No. 151, miscellaneous coke.

At 4.30 p. m. the right cylinder exhaust-valve stem became clogged, stopping the circulation of water; the valve became very hot and several premature explosions occurred. The valve stem was cleared by using air, under 160 pounds pressure, in reverse direction to the flow of water. During this time the load was necessarily reduced, dropping as low as two-thirds of full load for about 15 minutes. Immediately after the exhaust valve was cleared the engine carried full load and gave no further trouble during the remainder of the shift. The gas consumption, however, was large and continued high until 10 p. m., when a new setting of the air and gas valves materially lessened the amount used. This change is shown by the graphic log. Throughout the shift the fuel bed was easily kept in good condition and the gas was of uniform quality.

September 28: Except for a few back-fires the engine worked well and carried full load without difficulty during the morning shift. The producer was in good working order, but the coal differed from that used during the preceding shifts. A considerable proportion of the coal used for the test was slack, and as the supply ran from the delivery spout to the pile on the producer platform there was a mechanical separation, the lump coal rolling to one side, so that the center of the pile, used during this shift, was made up almost entirely of slack. The effect of charging slack is readily seen from the graphic log. The percentage of CO_2 in the gas gradually increased, while that of CO decreased; the average heat value of the gas fell about 10 B. t. u. during the shift and the fuel bed decreased in thickness, even though the coal was charged more frequently toward the end of the shift. This change in the charging interval was from 45 minutes to 30 minutes. Ordinarily the fuel bed was poked every 30 minutes, but during the last half of this shift it was poked every



*100 lb. charges used to this point inclusive, 125 lbs. after this point
▷ Calculated B.T.U. plotted

FIGURE 207.—Graphic log sheet, test No. 50, coke breeze.

15 minutes. With the decrease in the heat value of the gas there was a corresponding increase in the quantity of gas used, while the load remained practically constant.

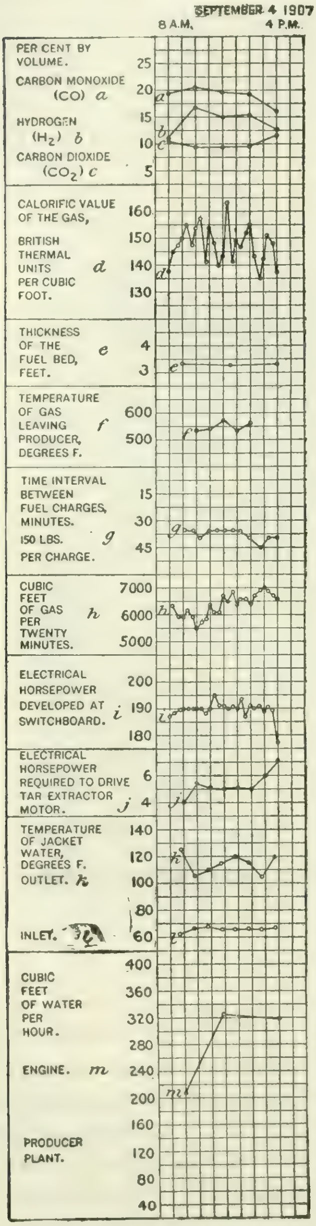


FIGURE 208.—Graphic log sheet, test No. 163, Jamestown No. 1 coal.

Except for a few light back-fires during the early part of the day shift, the engine worked well; the load, however, was not steady on account of a variable motor load. The coal still contained considerable slack and was charged every 30 minutes during the shift; the fuel bed was poked at 30-minute instead of 15-minute intervals as in the preceding shift. At 10 a. m. the ash bed was ground down, and for the next few minutes the heat value of the gas decreased about 10 B. t. u. per cubic foot, but it soon recovered, and with the exception of one or two variations was fairly uniform during the rest of the shift.

Throughout the evening shift the engine worked satisfactorily; the producer was in good condition and was easily operated. Beginning at 4 p. m., coal was charged every 40 minutes. At 10.30 p. m. the water supply from the local wells was temporarily interrupted and the low-pressure city water was resorted to. This supply was far from sufficient and it was necessary to reduce the load about half; after 20 minutes, however, well water was once more available and full load was again carried.

September 29: Throughout the morning shift the engine back-fired occasionally and there were a few premature explosions, but full load was easily maintained. The producer was in excellent condition, with the gas gradually increasing in heat value. After 2 a. m. coal was fired at 45-minute intervals.

The producer was in good working order and was easily handled during the day shift. The engine ran well until about 2 p. m., when the gas consumption was found to be unusually high, the temperature of the gas entering the engine was above normal, and it was very difficult to maintain the load. It was soon discovered that no water

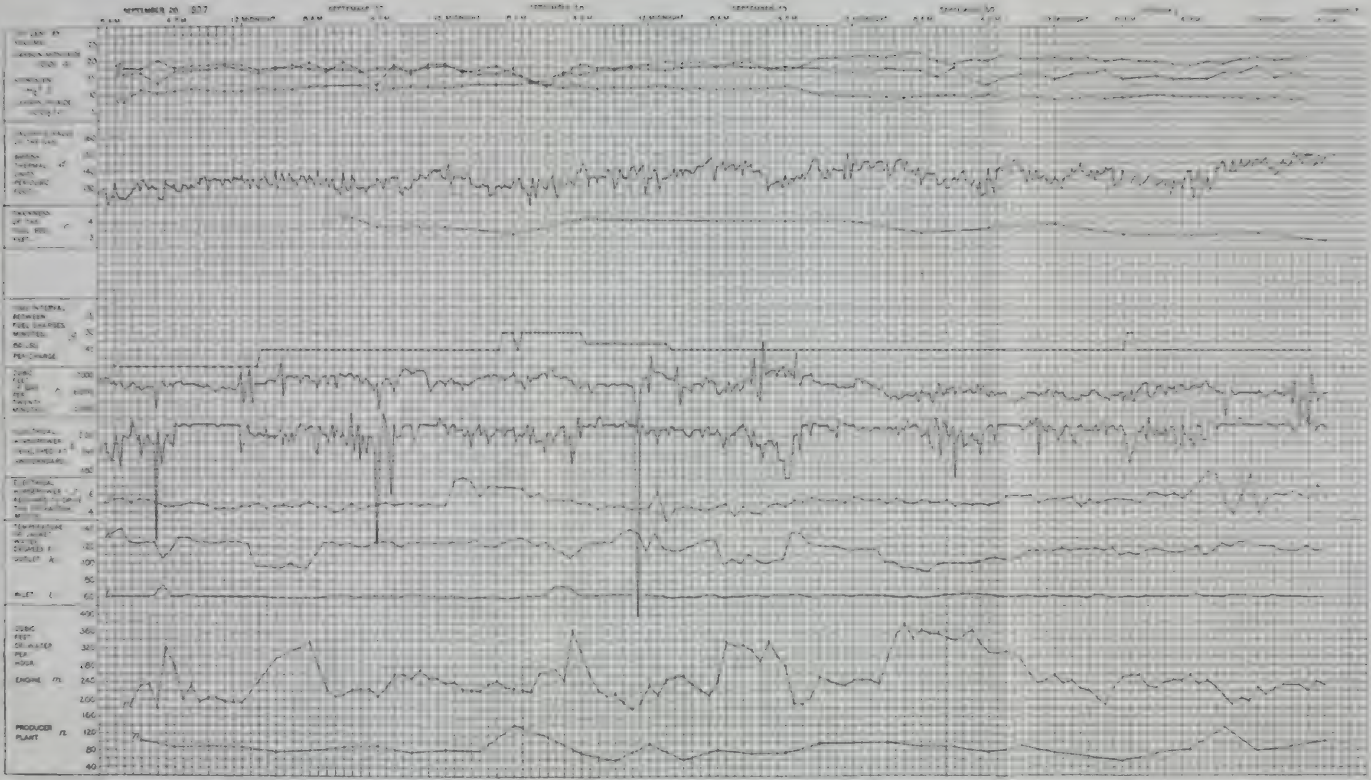


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FIGURE 50.—Graphic log sheet, test No. 164, Jamestown No. 3 coal.

was running through the tar extractor and that the gas was not properly cleaned and cooled. The water was at once regulated and at the end of the shift conditions were gradually improving, although the gas consumption was still high and the load was below normal.

During the first part of the evening shift the engine did not run as smoothly as usual and the gas consumption was rather high; but conditions were gradually improving, and at the end of the shift the engine was working satisfactorily and carrying full load. The automatic regulator controlling the supply of steam to the producer gave some trouble by imperfect action and caused sudden and irregular changes in the steam pressure at the producer blower. This did not continue long, however, and had no serious effect upon the fuel bed, which was in excellent condition.

September 30: Full load was carried from midnight to 8 a. m., with a gradually decreasing gas consumption. At 3.30 a. m. premature explosions began in the right cylinder, but ceased when the quantity of jacket water was increased. The producer worked satisfactorily and yielded a gas of uniform quality with a heat value of about 140 B. t. u. per cubic foot.

The engine ran smoothly and gave no trouble during the day shift, but the load fluctuated more than usual, due to a varying motor load. At 9.05 a. m the circuit breaker blew out. During this shift the producer required much attention; the coal charged was mostly slack and there was a tendency for blowholes to form in the fuel bed. Considerable extra poking given the fuel bed did not seriously affect the heat value of the gas. At 3.30 p. m. a leaky packing on the centrifugal pump interrupted the well-water supply and it became necessary to use city water for a short period. At this time the city pressure was sufficient to provide ample water, making it unnecessary to reduce the load.

During the first part of the evening shift there were several premature explosions. These were effectually stopped by allowing a small stream of water to flow into the air inlet; otherwise the engine ran satisfactorily and carried full load without difficulty. The fuel bed was not in good condition and there was still some tendency to form blowholes; the gas, however, was of good and fairly uniform quality. Throughout this shift the fuel bed was poked at frequent intervals and its condition gradually improved.

October 1: The engine ran steadily from midnight to 8 a. m., carrying full load on an average gas consumption, but with water running into the air inlet to prevent premature explosions. The producer was in good working order.

The engine ran satisfactorily throughout the day shift, but with a small stream of water running into the air inlet. The load was rather variable, due to fluctuations in the motor load. At 10.45 a. m.

the ignition circuit was changed from the motor generator set to the storage battery, and in so doing several charges misfired in the engine. Immediately a heavy explosion took place in the exhaust pipe and muffler, lifting the concrete cover of the muffler but doing no harm. Throughout this shift the producer worked well, yielding a gas of uniform quality. The coal fired was mostly slack.

The engine ran smoothly until 7.42 p. m., when a wire used to convey motion from the crank shaft to the indicator broke and fell across the igniter of the right cylinder, putting the whole ignition circuit out of use and stopping the engine. The trouble, when found, was at once remedied, the engine was immediately started, and in a short time a full load was again carried. The engine was stopped 11 minutes. The producer was in good working order during the entire shift.

October 2: The engine ran steadily and carried full load without difficulty throughout the morning shift. The fuel bed was in excellent condition, producing a gas of uniformly good quality. At 8 a. m. the test was brought to a close, after a run of 144 hours with both the producer and the engine in good working order. Graphic log is given on page 235.

JAMESTOWN No. 4.

Jamestown No. 4, test 165.—The fuel used during test 165, a New River run-of-mine coal, when delivered on the producer platform contained a large proportion of slack. It was a high-grade coal, containing less than 6 per cent ash, and having a heat value of 14,600 B. t. u. per pound as fired. In order to have a good fuel bed at the beginning of this run, regular firing was commenced immediately after the close of test 164. During the interval of 8 hours, between the two runs, the engine was carefully examined, the igniters were changed, and the jacket-water inlet to each cylinder was readjusted so as to equalize the distribution of water. At 3.20 p. m. the engine was started with the fuel bed in good condition and yielding gas with a heat value of about 135 B. t. u. per cubic foot. The official test began at 4 p. m.

Throughout the evening shift the producer worked well. The gas was of fairly uniform quality and had a heat value of about 135 B. t. u. per cubic foot. Coal was charged every 30 minutes until 9 p. m. when the charging interval was changed to 45 minutes as the fuel bed was gradually increasing in thickness. The engine ran steadily and carried full load.

October 3: The fuel bed was in excellent condition and worked well until 2.40 a. m., when the heat value of the gas decreased about 20 B. t. u. per cubic foot. It was soon discovered that the vibration of the tar extractor had nearly closed a steam-pipe valve and thereby

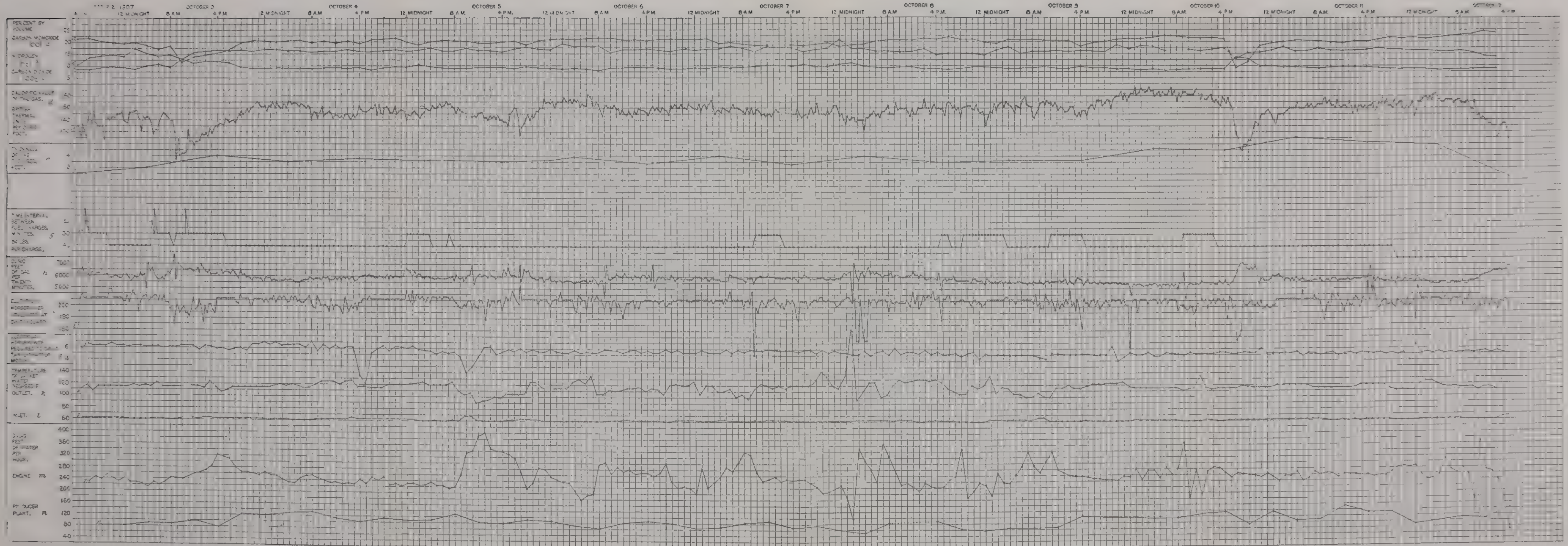

FIGURE 210.—Graphic log sheet, test No. 185, Jamestown No. 1 coal.

cut off the necessary amount of steam for the blast. As soon as the valve was opened the gas began to improve in quality, and in a short time conditions were normal. Soon after 4 a. m., however, the gas again decreased in heat value. The ash bed was high and the fuel bed was rather thin, so the 30-minute interval between fuel charges was restored and the heat value of the gas increased gradually from 130 B. t. u. to 145 B. t. u. per cubic foot. Throughout the shift, which ended at 8 a. m., the engine worked well, carrying full load except for a few minutes during the partial closing of the steam valve, already referred to. Even at this time, however, the load was only slightly reduced.

At the beginning of the day shift the heat value of the gas was gradually diminishing, the ash bed was high, the fuel bed was hot, and there was a blowhole in one side of the fuel bed. At 8.30 a. m. the ash bed was ground down about 5 inches and the heat value of the gas decreased to 110 B. t. u. per cubic foot. The gas consumption increased from 6,200 cubic feet to 6,700 cubic feet per 20 minutes, although the load was reduced about 10 per cent. About 2 hours after the ash bed was ground down the heat value of the gas began to increase and at the end of the shift was about 135 B. t. u. per cubic foot. At the same time the gas consumption decreased gradually to about 6,000 cubic feet per 20 minutes. The engine load fluctuated considerably during the day on account of a variable motor load. At 3.05 p. m. the circuit breaker blew out.

At the beginning of the evening shift the condition of the fuel bed was steadily improving. At 5.45 p. m. the interval between fuel charges was again changed to 45 minutes. The heat value of the gas gradually increased until 9 p. m., when it was about 150 B. t. u. per cubic foot, and during the rest of the shift it was fairly uniform. The engine ran satisfactorily and carried a steady full load.

October 4: Throughout the morning shift the producer worked exceptionally well, yielding gas with a heat value of about 150 B. t. u. per cubic foot. The average gas consumption was 5,600 cubic feet per 20 minutes. The engine ran steadily, easily carrying full load.

The fuel bed was in excellent condition from 8 a. m. to 4 p. m., and the gas was of uniformly good quality. The engine ran satisfactorily and gave no trouble. At 3.19 p. m. the circuit breaker blew out.

The producer worked satisfactorily during the evening shift, generating gas with a heat value of about 150 B. t. u. per cubic foot. At 10 p. m. the ash bed was ground down 3 or 4 inches without affecting the quality of the gas. The engine required little attention, and ran steadily with a full load, consuming about 6,000 cubic feet of gas per 20 minutes.

October 5: The producer was in good condition and yielded a gas of uniform quality throughout the morning shift. At 4 a. m. the charging interval was changed to 45 minutes. The engine ran steadily, carrying full load, and most of the time the gas consumption was less than 6,000 cubic feet per 20 minutes.

The producer worked well during the day shift, generating gas with a heat value of about 140 B. t. u. per cubic foot. At 9.20 a. m. one of the brushes on the tar-extractor motor was found to be in bad condition. The motor was stopped 55 minutes for repairs, and during this time uncleaned gas was used. No ill effects were noted on account of the tar, but it is probable that difficulty would have resulted if the gas had been used much longer without cleaning. At 9.30 a. m. the centrifugal pump was shut down for adjustment and the water for the engine was taken from the city main, being supplied through the steam pump in order to get the necessary pressure. The city water was 8° to 10° F. warmer than the well water and soon after the change was made several premature explosions occurred. By increasing the quantity of jacket water the temperature of the water leaving the engine jackets decreased from 120° to 100° F. and the preignitions ceased. After about 2 hours the centrifugal pump was again in good order and well water was available. The engine thereafter ran satisfactorily, on an average carrying full load with a gas consumption of about 6,000 cubic feet per 20 minutes.

The ash bed was rather high at the beginning of the evening shift, and at 6 p. m. it was ground down 3 or 4 inches. During the next hour the heat value of the gas gradually decreased from 150 B. t. u. to 125 B. t. u. per cubic foot, and for the next 3 hours it increased gradually to about 155 B. t. u. per cubic foot, where it remained fairly constant. The engine ran well throughout the shift, carrying full load even during the period of wide variation in the quality of the gas caused by grinding down the ash bed. During this time, however, the ratio of air to gas was changed several times by the engine operator.

October 6: Throughout the morning shift the producer was in excellent condition and yielded a rich gas with a heat value of about 155 B. t. u. per cubic foot. Full load was easily maintained with a gas consumption of approximately 5,700 cubic feet per 20 minutes.

The producer was in good order and gave a gas of uniform quality throughout the day shift. There were several premature explosions in the engine cylinders, although the outlet temperature of the jacket water was only 110° F. These explosions were stopped by allowing a small amount of water to drip into the air inlet.

Throughout the evening shift both the engine and the producer worked satisfactorily. The fuel bed was in excellent condition and gave a gas with a heat value of about 150 B. t. u. per cubic foot. The engine ran steadily, carrying full load on a gas consumption of about 5,800 cubic feet per 20 minutes.

October 7: At the beginning of the morning shift smoke appeared at the crank-case vent, and it was soon found that the center cylinder was "blowing" past the piston. The ignition on this cylinder was set a little later and more oil was put into the crank case; this seemed to reduce the "blowing," and by 7.30 a. m. it was no longer discernible. The condition of the fuel bed continued to be good but the ash bed was high, and at 2 a. m. it was ground down about 4 inches with no noticeable effect on the quality of the gas. The engine ran steadily and carried full load.

At the beginning of the day shift the fuel bed, although rather thin, was in good condition and gave a gas with a heat value of about 145 B. t. u. per cubic foot; this was, however, a little lower than the average heat value of the gas for the preceding shift. From 10 a. m. to 2 p. m. fuel was charged at 30-minute intervals and after that at 45-minute intervals. On the average a full load was carried with a gas consumption of about 6,000 cubic feet per 20 minutes. As a precaution against premature explosions, a small amount of water was allowed to drip into the air inlet of the engine. At 9.40 a. m. the water pressure increased a little and caused an excess of water to enter the inlet. Before this was noticed an occasional charge misfired and the engine began to slow down; the water was immediately turned off and the load reduced a little; the engine responded at once and in a few minutes it was carrying full load under normal conditions. During the remainder of the shift the engine worked satisfactorily.

The fuel bed was in good condition throughout the evening shift. The gas was of uniformly good quality, and the engine ran well and carried full load except for a few minutes at 10.15 p. m., when an exhaust valve caused trouble by sticking. This was soon remedied, however, but for 2 minutes the load was only two-thirds full load.

October 8: The fuel bed was in excellent condition and the gas was of good quality throughout the morning shift. About 1 a. m. the temperature of the jacket water at the outlet was 135° F; this was a little higher than the usual temperature, and the water valve was opened wider, supposedly admitting more water to the engine jackets. The temperature continued to increase, however, and soon reached 212° F. At this time the load was taken off the engine and an attempt was made to locate the trouble. It was soon found that the water meter had become clogged or stuck, shutting off the water supply. The meter was immediately by-passed and the engine cooled rapidly. The load was off 16 minutes; after this time the engine carried about five-sixths full load until 4.40 a. m., when full load was restored. The water meter was by-passed but a few minutes, then the by-pass was slowly closed and the meter ran all right. At the beginning of the shift the gas pressure in the top of the producer, ordinarily equal to 1½ to 2½ inches of water, was higher than usual and gradually increased until at 5.30 a. m. it equaled 7 inches of water. A short horizontal pipe between the producer and scrubber was found to be about two-thirds filled with dirt and soot, so that the usual quantity of gas could not pass at the normal pressure. The pipe was cleared by loosening the soot with a bar; the flow of gas carried the soot into the scrubber and the gas pressure became normal.

Throughout the day shift the producer worked well, yielding a gas with a heat value of about 150 B. t. u. per cubic foot. The engine ran satisfactorily and carried an average full load with a gas consumption of about 6,000 cubic feet per 20 minutes.

At the beginning of the evening shift the fuel bed was rather thin and the interval between charges was changed from 45 minutes to 30 minutes. The gas was of good quality. The engine ran steadily and carried full load with a gas consumption of from 5,600 to 6,000 cubic feet per 20 minutes.

October 9: After 3 a. m. coal was charged at 45-minute intervals. During the shift ended at 8 a. m. the average heat value of the gas increased about 10 B. t. u. per cubic foot and at the close of the shift the fuel bed was in excellent condition. The engine ran satisfactorily, carrying a steady full load with a gas consumption of approximately 5,600 cubic feet per 20 minutes.

Throughout the day shift the engine worked well, carrying full load. At 8 a. m. the centrifugal pump was stopped for repairs and water was taken from the city mains until 10 a. m., when the pump was again in service. The fuel bed was in good condition and the gas was of good quality, but the ash bed was high, and at 11 a. m. the interval between fuel charges was changed to 30 minutes in order to build up a thicker fuel bed before grinding down. At 2.30 p. m. the ash bed was ground down about 3 inches and the heat value of the gas decreased a little.

Throughout the evening shift the heat value of the gas gradually increased from 145 B. t. u. to 160 B. t. u. per cubic foot. The fuel bed was thicker at 4 p. m. than at any preceding time during the test. The engine ran well, carrying full load with a gas consumption of from 5,300 to 5,400 cubic feet per 20 minutes, that gradually decreased as the heat value of the gas increased. At 11.30 p. m. the right cylinder exhaust-valve spring broke. The engine was not stopped, but the load was reduced approximately one-half for about 30 minutes while the broken spring was repaired, after which full load was again carried.

October 10: Throughout the morning shift the producer was in good condition and yielded an exceptionally rich gas with an average heat value of 163 B. t. u. per cubic foot. The engine ran steadily, carrying full load with a gas consumption of from 5,200 to 5,300 cubic feet per 20 minutes. The repaired exhaust-valve spring gave no trouble.

The fuel bed was in good condition and the gas was of good quality throughout the day shift. The ash bed, however, was high, and from 9 a. m. to 2 p. m. coal was charged at 30-minute intervals in order to build up the fuel bed before grinding down. The engine ran steadily and carried full load. At 5 p. m. the ash bed was ground down, but as the fuel bed was not lowered the ash bed was again ground down at 5.30 p. m. This second grinding down was excessive, for the fuel bed was badly broken up and the heat value of the gas began to decrease. Simultaneously the water outlet to the scrubber became partly clogged and water rose in the scrubber, partly closing the gas inlet. The blast was thus automatically increased to a maximum, and the strong blast through the badly broken up fuel bed served to lower still further the heat value of the gas, which decreased between 5 p. m. and 6.30 p. m. from 160 B. t. u. to about 115 B. t. u. per cubic foot. Although the load was reduced somewhat the gas consumption increased to about 7,000 cubic feet per 20 minutes. With careful attention conditions began to improve, and after 7 p. m. the heat value of the gas increased steadily to about 150 B. t. u. per cubic foot; the blast pressure became normal and the usual load was carried. The load had been reduced to five-sixths full load for about 1 hour. At 11 p. m. the fuel bed was in good condition and yielded gas of good quality. Coal was charged at 45-minute intervals throughout the shift. The engine worked well, but it was necessary to change the air and gas valve settings at frequent intervals on account of the variation in the heat value of the gas.

October 11: The fuel bed was in good condition throughout the morning shift. The gas was of fairly uniform quality and had a heat value of about 150 B. t. u. per cubic foot. The engine ran well, carrying a steady full load with a gas consumption of about 5,650 cubic feet per 20 minutes.

The producer worked well throughout the day shift and the gas was of good quality. The engine carried an average full load, although there was an unusually variable motor load.

Throughout the evening shift the engine ran satisfactorily on a good quality of gas. The fuel bed was in good condition, although it was much thicker than at the beginning of the run. In order to end the test with approximately the same thickness of fuel bed as at the start, after 8 p. m. coal was charged only once an hour.

October 12: Throughout the morning shift the fuel bed was in excellent condition and the gas had a heat value of about 158 B. t. u.

per cubic foot. The engine ran steadily, carrying a full load, with a gas consumption of 5,300 to 5,600 cubic feet per 20 minutes.

As the fuel bed was still much thicker at the beginning of the day shift than at the beginning of the run, no coal was charged until 2.30 p. m. At 9 a. m. the heat value of the gas began to diminish gradually, and at 2 p. m. decreased about 10 B. t. u. per cubic foot. The fuel bed was approaching the required thickness, but the possibility of maintaining full load until 4 p. m. without additional fuel was doubtful. At 2.30 p. m. a double charge of coal was made, which was the last charge during the test. Following this charge the heat value of the gas increased 10 to 12 B. t. u. per cubic foot and remained at the new figure until nearly 4 p. m., when it again decreased about 10 B. t. u. per cubic foot. At 4 p. m. the test was brought to a close with the engine running satisfactorily under practically full load. The producer was in good working order and, although the heat value of the gas at the close of the run was rather low, the fuel bed was in good condition and of practically the same thickness as at the start. Graphic log is given on page 236.

JAMESTOWN No. 5.

Jamestown No. 5, test 166.—The fuel used during test 166 was a New River run-of-mine coal. It was much like Jamestown No. 4 in appearance, but did not have so high a heat value and contained a little more ash.

October 14: At 1.50 p. m. the engine started with a light load, but after 3.15 p. m. full load was easily carried. The official test began at 4 p. m. Coal was charged at 30-minute intervals at the start, but after 6 p. m. charges were made once every 45 minutes. The engine ran steadily with full load, and the fuel bed was in excellent condition, giving a rich gas of uniform quality. The air inlet to the producer blower was opened much wider at the beginning of this test than on any previous run, with the result that the percentage of CO_2 in the gas was much lower.

October 15: During the morning shift the distribution of the blast through the fuel bed was not even, and the gas, although of good quality, varied in heat value from 146 B. t. u. to 164 B. t. u. per cubic foot. The engine, however, ran without difficulty and carried full load with a gas consumption of 5,100 to 5,400 cubic feet per 20 minutes.

Throughout the day shift the producer worked well. The coal, charged at 45-minute intervals, was about one-half slack. The heat value of the gas was fairly uniform at about 155 B. t. u. per cubic foot. The engine ran steadily under full load, although the motor load was more variable than usual.

During the evening shift the fuel bed was in exceptionally good condition and gave a rich gas of uniform quality. At 8 p. m. the ash

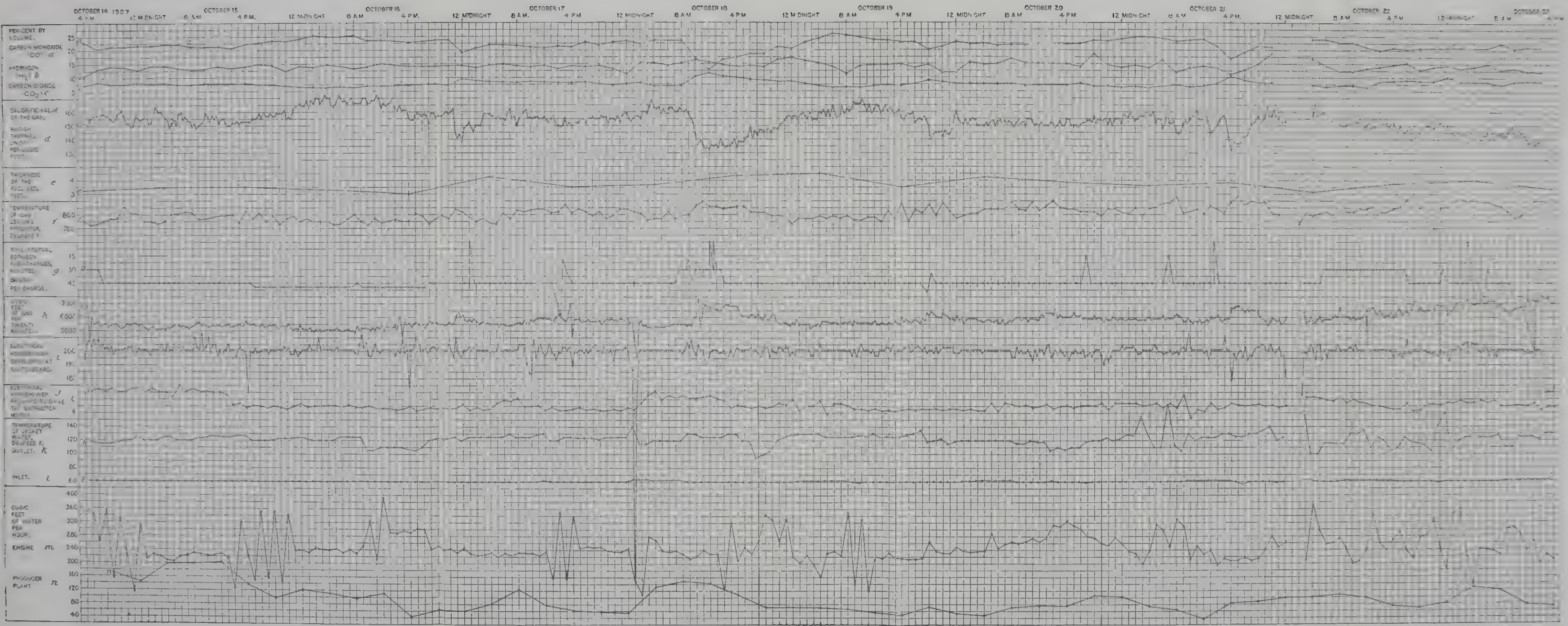

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FIGURE 211.—Graphic log sheet, test No. 16b, Jamestown No. 5 coal.

bed was ground down about 4 inches; the fuel bed settled nicely, and no change was noticed in the heat value of the gas. Coal was charged at 50-minute intervals, and although over half slack it gave no trouble in the producer. The engine ran satisfactorily, carrying full load. At 8.30 p. m. there were premature explosions in the right cylinder The gas valve was closed a little and the preignitions stopped; but with this new setting of the gas valve the engine would not carry full load. The valve was consequently opened gradually and no premature explosions resulted.

October 16: The fuel bed was in excellent condition throughout the morning shift in spite of the fact that the coal charged was about three-fourths slack. The heat value of the gas was very high, averaging about 170 B. t. u. per cubic foot. The engine carried steady full load with a gas consumption of about 5,100 cubic feet per 20 minutes.

During the first half of the day shift the fuel bed was in excellent condition and the gas had an average heat value of 170 B. t. u. per cubic foot. At 1.20 p. m. more steam was tried in the blast, and in a short time the heat value of the gas decreased 10 to 12 B. t. u. per cubic foot, while the fuel bed hardened and became more difficult to keep in good working order. When the steam supply was reduced to the original amount the heat value of the gas did not increase, but the condition of the fuel bed soon improved. The engine carried full load and some of the time a considerable overload. The proportions of air and gas in the explosive mixture were changed several times during the shift. Although the jacket-water temperature was normal, there were a few premature explosions, but preignitions were stopped by allowing a small stream of water to run into the air inlet.

At the beginning of the evening shift the fuel bed was in good working order, and the gas was of good quality. The ash bed, however, was high, and at 6 p. m. it was ground down about 2 inches, and at 10 p. m. 2 inches more, without affecting the quality of the gas. The coal charged during the shift was at least three-fourths slack, and most of the time it worked exceptionally well. At 11 p. m., however, a blowhole formed on one side of the fuel bed, and before it was properly filled up the heat value of the gas decreased about 20 B. t. u. per cubic foot. The engine worked well throughout the shift.

October 17: During the first half of the morning shift the blowhole formed during the preceding shift was gradually filled up. At 1 a. m. a double charge of coal was fired and worked into the blowhole, and at 3 a. m. the fuel bed was in good condition, yielding a gas with a heat value of about 160 B. t. u. per cubic foot. Throughout this shift the coal fired was practically all slack, but it gave no trouble. The engine carried a steady full load and ran satisfactorily, but as the heat value of the gas varied it was necessary to change the air and gas valve setting at frequent intervals. During the shift the heat value of the gas increased about 20 B. t. u. per cubic foot and the gas consumption decreased from 6,200 cubic feet to about 5,400 cubic feet per 20 minutes.

The fuel bed was in good working order throughout the day shift and yielded gas of a fairly uniform quality. During the last half of the shift the taking of temperature measurements at different parts of the fuel bed interfered to a certain extent with the regularity of charging coal and poking, and the action of the engine seemed to indicate that the heat value of the gas varied much more than was shown by the calorimeter. This fluctuation made it necessary to watch the engine and to change the air and gas-valve settings frequently. The engine, however, carried the usual load, although this was somewhat variable, owing to the fluctuating motor load.

The fuel bed was in good condition and generated a gas with an exceptionally uniform heat value averaging about 155 B. t. u. per cubic foot throughout the evening shift. Coal was charged every 45 minutes. The engine ran steadily with full load with a gas consumption of about 5,700 cubic feet per 20 minutes.

October 18: At the beginning of the morning shift the commutator brushes on the centrifugal-pump motor gave considerable trouble by sparking and it was found necessary to shut down the motor. City water was then used for cooling the engine jackets, and as the water pressure was too low to give a sufficient supply of water with full load on the engine, the load was reduced. At 1.45 a. m. the steam pump was started, supplying city water at the necessary pressure, and during the remainder of the shift a steady full load was carried.

At 9 a. m. the ash bed was ground down and the fuel bed was badly broken up, as it did not settle uniformly. During the next hour the heat value of the gas decreased about 25 B. t. u. per cubic foot and during the remainder of the day shift averaged about 135 B. t. u. per cubic foot. The engine worked well, however, and carried full load, although it was necessary to change the air and gas valve settings from time to time on account of variations in the quality of the gas. At 9 a. m. the centrifugal pump was again started and well water was used in place of city water. The coal fired was about three-fourths slack, and until 2 p. m. it was charged once every 45 minutes.

At the beginning of the evening shift the fuel bed was in poor order, but its condition improved steadily and the heat value of the gas increased about 20 B. t. u. per cubic foot before the end of the shift. The gas consumption fell from 6,800 cubic feet to about 5,500 cubic feet per 20 minutes. The engine ran steadily and carried full load.

October 19: At the beginning of the morning shift the blast had a tendency to blow around the edge of the fuel bed, but the gas was of good quality and its heat value was increasing. At the end of the shift the fuel bed was in excellent condition and the heat value of the gas was about 160 B. t. u. per cubic foot. The coal, which was about three-fourths slack, was charged at 45-minute intervals. The engine carried a steady full load with a gas consumption of about 5,500 cubic feet per 20 minutes.

The fuel bed was in excellent condition during the entire day shift, and the heat value of the gas was high and fairly uniform. Except for a few premature explosions the engine ran satisfactorily and carried full load.

At the beginning of the evening shift the fuel bed was in good working order. The coal was practically all slack. The ash bed was rather high, and at 7.30 p. m. it was ground down 5 inches; the fuel bed settled well, but the heat value of the gas decreased about 10 B. t. u. per cubic foot and was rather variable during the remainder of the shift. This made it necessary to watch the engine closely and from time to time to change the air and gas-valve settings. The engine did not run as smoothly as usual, but carried full load with a gas consumption varying from 5,600 cubic feet to 6,400 cubic feet per 20 minutes.

October 20: During the first part of the morning shift the operation of the engine indicated the presence of tar in the gas, and it was soon found that the amount of water running through the tar extractor was considerably less than usual. The supply of water was immediately increased and no further indications of tar in the gas were noticed. The engine carried a steady full load throughout the shift and the producer was in good working order, supplying a gas of uniformly good quality.

The fuel bed was in excellent condition and the gas was of uniform quality during the entire day shift. The coal was practically all slack. The engine carried full load but did not run steadily and consumed an unusually large quantity of gas when the high quality of the latter is considered.

Throughout the evening shift the fuel bed was in good working order and the gas was of uniform quality. The coal was mostly slack. There were several premature explosions in the right cylinder but the engine otherwise gave no trouble and carried full load.

October 21: The fuel bed was in good condition. During the 32 hours up to and including the morning shift the maximum variation in the heat value of the gas was only 12 B. t. u. per cubic foot, this value ranging from 148 B. t. u. to 160 B. t. u. per cubic foot. The ash bed was high, and instead of grinding down all the ash at one time it was ground down a little at a time at intervals of 1 hour for 3 successive hours. This did not affect the heat value of the gas to any great extent, although at the last grinding down the blast had a tendency to blow around the edge of the fuel bed and the heat value of the gas decreased 8 to 10 B. t. u. per cubic foot. The engine carried full load, although at times there were several premature explosions.

At the beginning of the day shift the blast had a tendency to blow around the edge of the fuel bed, but by working the coal from the center toward the edge this was overcome and the heat value of the gas increased 10 to 15 B. t. u. per cubic foot. At 12.20 p. m. the ash bed was ground down 5 inches and the heat value of the gas decreased 10 B. t. u. per cubic foot, but this loss was entirely made up during the next 2 hours. At 3 p. m. the ash bed was ground down again and the heat value of the gas decreased to 130 B. t. u. from an average of about 155 B. t. u. per cubic foot. At this time the load was reduced slightly for a few minutes while the air and gas valves were readjusted. Throughout this shift the engine did not run satisfactorily, giving considerable trouble from preignitions.

At the beginning of the evening shift the heat value of the gas was about 130 B. t. u. per cubic foot, but it steadily increased until 9 p. m., after which time it was fairly uniform at approximately 160 B. t. u. per cubic foot. The fuel bed was in good condition. The coal, mostly slack, was charged every 45 minutes. The engine ran more steadily than during the preceding shift and easily carried full load. As the gas increased in heat value the consumption decreased from 6,800 cubic feet to 5,700 cubic feet per 20 minutes.

October 22: The fuel bed was in good condition during the entire morning shift, yielding a gas with a heat value of about 155 B. t. u. per cubic foot. Coal, mostly slack, was fired once every 45 minutes until 5.30 a. m., after which time it was charged at 30-minute intervals. At 12.12 a. m. the igniter on the center cylinder short-circuited, putting the whole ignition circuit out of use, and before the trouble was located and remedied the engine stopped after a continuous run of 178 hours. The engine was started again, however, at 1.45 a. m. In a short time it was carrying full load and throughout the rest of the shift it ran without difficulty.

The producer was in excellent condition throughout the day shift. The gas was of uniform quality and had an average heat value of about 150 B. t. u. per cubic foot. The engine carried full load, but did not run easily and consumed a large quantity of gas considering the high quality of the latter.

Throughout the evening shift the fuel bed was in good condition and the gas had an average heat value of about 150 B. t. u. per cubic foot. The coal was mostly slack and after 6.15 p. m. it was charged at 45-minute intervals. The engine ran fairly well, carrying full load, but with a high gas consumption, averaging about 6,600 cubic feet per 20 minutes.

October 23: At the beginning of the morning shift the gas pressure in the producer was unusually high, as was also the blast pressure, owing to clogging of the gas pipe between the producer and the scrubber. An effort was made to clear the pipe by poking with a bar, and although conditions improved somewhat this method was not very effective, for the soot was hard and adhered firmly to the sides of the pipe, making it difficult to remove while the producer was in operation. The coal charged was fine and rather dry, and because of the high-blast pressure it had a tendency to blow over into the scrubber, adding to the accumulation of soot in the pipe. After 3 a. m. the fuel was moistened before firing and the quantity of fine coal blown into the pipe was thus considerably reduced. From the beginning of the shift the temperature of the fuel bed gradually increased, and at 3 a. m. the entire bed was in rather poor condition; the bed was very hot and the center was so pasty that the blast could get through only around the edge. The ash bed was ground down a little at intervals of 1 hour, more to loosen up the fuel bed than to remove the ash. The fuel bed was thoroughly poked every 20 minutes for a period of 2 hours, and during this time the air inlet of the blower was nearly closed for 15 minutes, so that a large excess of steam entered the producer. The effect of this was to decrease the quantity of clinker and to cool the fuel bed. After some time conditions began to improve, and at 8 a. m. the fuel bed, although not in good condition, was in much better working order. Although the heat value of the gas varied from 135 B. t. u. to 150 B. t. u. per cubic foot, it was exceptionally uniform considering the conditions under which the producer worked. The engine carried full load for the entire shift; but it did not work easily and gave trouble by frequent preignitions. The gas consumption was very high, averaging 7,000 cubic feet per 20 minutes.

The amount of coal available for the run was nearly exhausted and it was necessary to close the test at the end of the day shift. The fuel bed, although in rather poor working order, was in much better condition than during the preceding shift, but the gas pressure was still high. As the fuel bed was considerably thicker than at the start of the test, little coal was fired in order that the thickness of the bed at the close of the test might be the same as at the beginning. The heat value of the gas decreased steadily during the shift, falling from 145 B. t. u. to about 125 B. t. u. per cubic foot. The engine carried full load until 2.40 p. m., when it was reduced about one-sixth. The engine did not run easily and the gas consumption was high. The engine was shut down soon after 4 p. m., and the test was brought to a close.

After the test the engine was overhauled and the pistons were found to be in bad condition, with the piston rings firmly embedded in carbonized oil. There was also a considerable accumulation of carbonized oil on the piston heads. This condition was plainly the cause of the high gas consumption and the unusually numerous preignitions. The oil used was on trial for gas-engine purposes and was of lower grade than any previously used in this engine. The gas pipe connecting the producer and the scrubber was opened and cleaned out. It was found to be from one-half to two-thirds full of soot and ashes, which had blown over from the producer. The soot had hardened and adhered firmly to the walls of the pipe, forming a restriction which was the cause of the high gas pressure during the last part of the test. Graphic log is given on page 242.

JAMESTOWN No. 7.

Jamestown No. 7, test 167.—After the close of test No. 166 it was decided not to run another long test until an oil could be procured which was adapted for use in the gas engine. In the meantime the engine was put in good condition and started for a short test of a New River run-of-mine coal designated "Jamestown No. 7." This coal had a heat value of about 14,600 B. t. u. per pound and was low in ash. As delivered on the producer platform it was about one-fourth slack.

October 24: When the engine was started at 7 p. m. the fuel bed was in excellent condition. The 44-hour period upon which the computations of the test are based began at 8 p. m., and throughout the shift from this time until midnight both the engine and producer worked satisfactorily.

October 25: At the beginning of the morning shift the fuel bed was in good condition, and the gas was of good and fairly uniform quality. At 1 a. m. the centrifugal pump was shut down on account of the motor brushes sparking badly, and while they were being repaired city water was used in the engine jackets. Coal was charged at 30-minute intervals throughout the shift. The engine ran well and carried full load.

Throughout the day shift the fuel bed was in excellent condition. However, the heat value of the gas varied considerably, making it necessary to change the air and gas valve settings from time to time. At 10.25 a. m. the indicator cock on the center cylinder began to leak badly and was taken out. This required but a few minutes, during which time there was practically no load on the engine. Except for this interruption the engine ran satisfactorily and carried full load without difficulty.

The fuel bed was in satisfactory condition during the entire evening shift and produced a gas with an average heat value of about 150 B. t. u. per cubic foot. After 8 p. m. coal was charged at 45-minute intervals. At 4 p. m. the engine began to back-fire badly and soon after a short circuit occurred in the right cylinder igniter. The load was taken off and the igniter was changed without stopping the engine. The back-firing continued at frequent intervals until 5 p. m., when it finally stopped; full load, however, was not carried until 7 p. m., but throughout the rest of the shift the engine ran satisfactorily and carried full load.

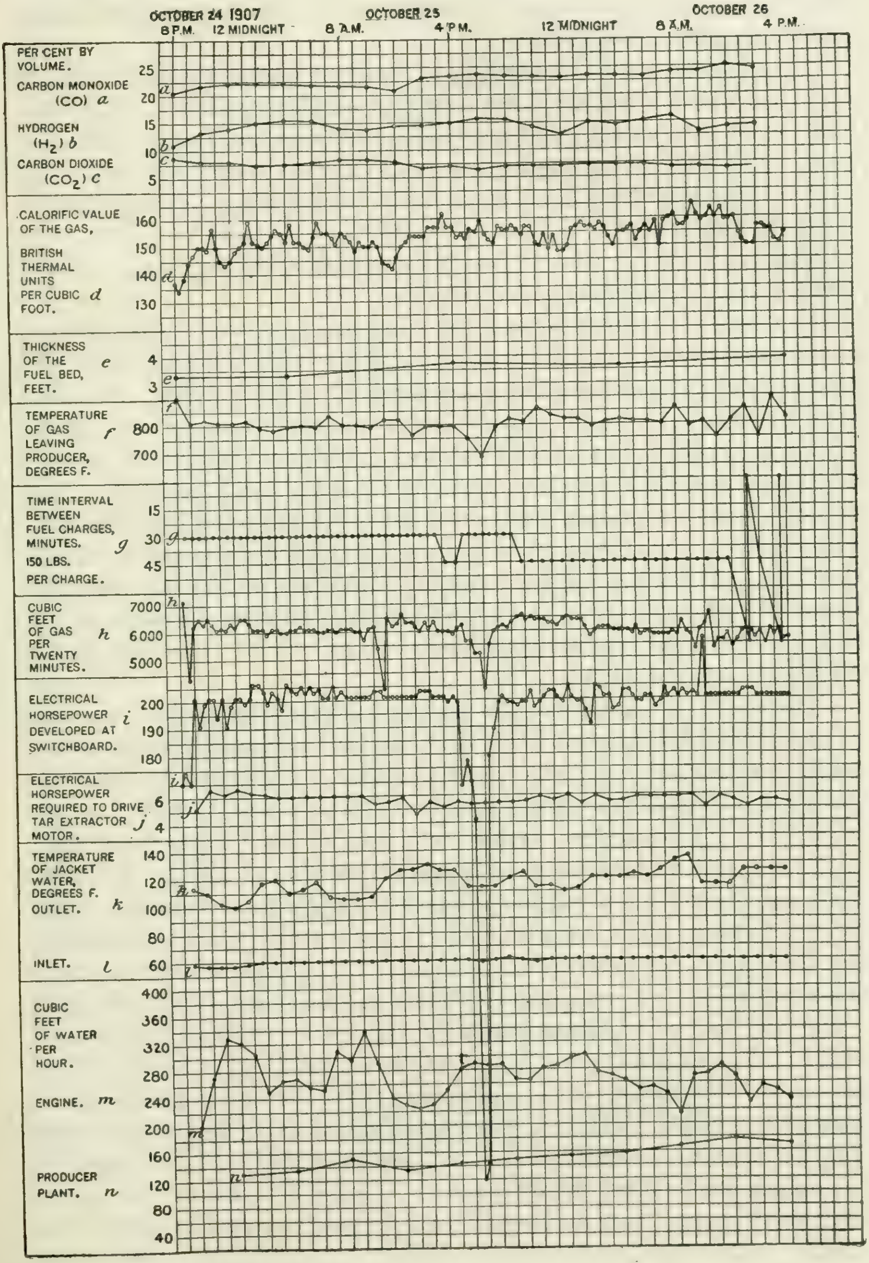

FIGURE 212.—Graphic log sheet, test No. 167, Jamestown No. 7 coal.

October 26: The fuel bed was in good condition and the gas was of uniformly good quality throughout the morning shift. The ash bed was high, and from 1.50 a. m. to 3.50 a. m. it was ground down several times, but each time only slightly. The fuel bed was settled nicely, without breaking up and without affecting the heat value of the gas. The engine ran satisfactorily, carrying full load with a gradually decreasing gas consumption.

During the day shift the taking of fuel-bed temperatures interfered with the regular poking and charging of the producer. The gas, however, was of fairly uniform quality and the fuel bed remained in good condition. The engine ran well, always under full load and with an overload for about 12 per cent of the time. Graphic log is given on page 249.

Jamestown No. 7, test 168.—The coal used during this test was identical with that used in test No. 167.

October 30: Before starting the run the crank-case oil in the gas engine was taken out, the engine thoroughly cleaned, and oil of better grade than that used in preceding tests was supplied. Coal was then charged at regular intervals for some time in order to build up the fuel bed to the usual thickness. This coal, however, charged when the producer was in a state of rest and with but little blast pressure, had a tendency to form a heavy, sticky, and cold fuel bed. The engine was started at 9.15 p. m. on rather poor gas and with partial load. With the engine running, the condition of the fuel bed began to improve, the heat value of the gas steadily became greater and the load was gradually increased to full load. The test proper was begun at midnight.

October 31: Throughout the morning shift the fuel bed was still in poor condition, being so cold and hard in the center that the blast could get through only the outer portions. The heat value of the gas increased gradually from 135 B. t. u. to about 155 B. t. u. per cubic foot. The engine carried an irregular but average full load. At 3.45 a. m. the jacket-water temperature was about 20° F. higher than usual and a few slight premature explosions occurred in the right cylinder. The amount of jacket water was immediately increased and the preignitions stopped. The coal, which was more than half slack, was charged at 45-minute intervals during the shift.

The ash bed was high at 8.50 a. m. and was ground down about 6 inches. The heat value of the gas fell from 160 B. t. u. to 140 B. t. u. per cubic foot during the next hour, but afterwards gradually increased to about 150 B. t. u. per cubic foot and averaged that during the rest of the day shift. The fuel bed was still cold and pasty in the center and rather firmly packed. From 2 p. m. to 4 p. m. no coal was charged, but at 30-minute intervals the fuel bed was thoroughly poked in an attempt to better its condition. The engine carried full load and worked well, except for a few premature explosions in the right cylinder; these were stopped by allowing a very small amount of water to flow into the air inlet.

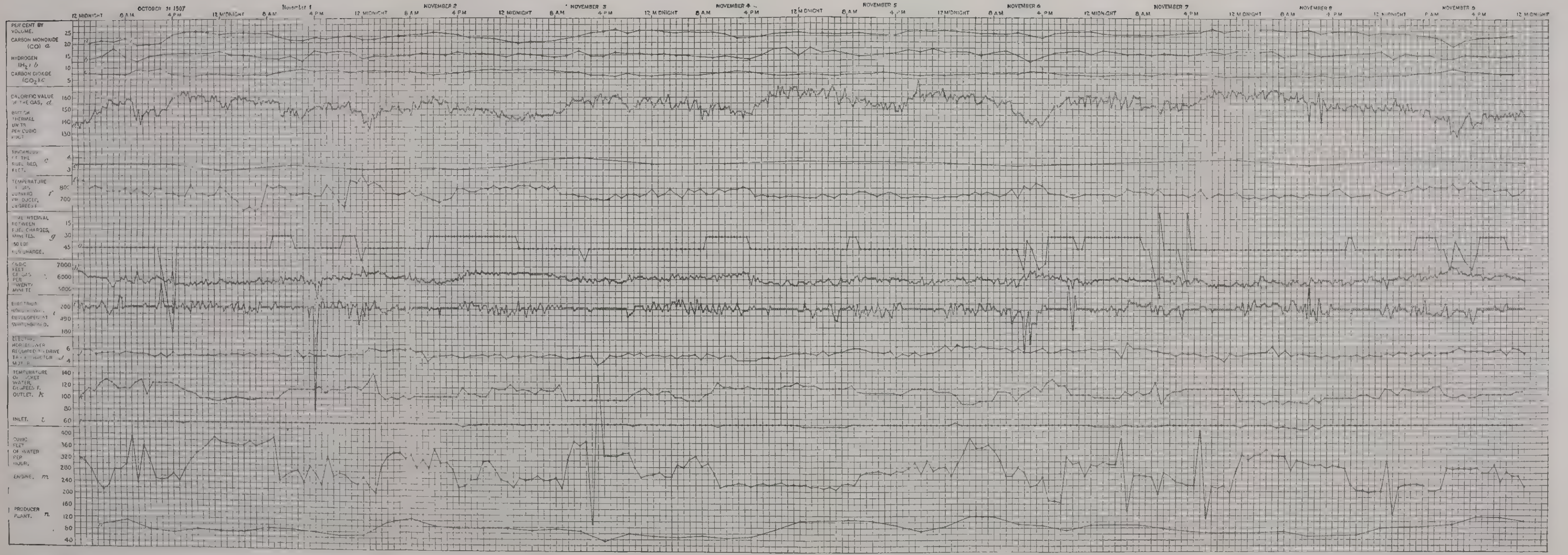

FIGURE 213.—Graphic log sheet, test No. 168, Jamestown No. 7 coal

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At the beginning of the evening shift the fuel bed was in much better condition. The gas was of uniform quality and had a heat value of about 160 B. t. u. per cubic foot. The coal, which was about three-fourths slack, was charged at 45-minute intervals. At 10 p. m., although the jacket-water temperature was low and water was running into the air inlet, there were frequent preignitions in the right cylinder. At 11 p. m. the engine was running satisfactorily, carrying full load.

November 1: The producer was in good condition and yielded a rich gas during the entire morning shift. The engine ran steadily, with full load, and worked well except for an occasional premature ignition in the right cylinder.

The ash bed was rather high and was ground down a little at hourly intervals during the day shift. The heat value of the gas decreased about 10 B. t. u. per cubic foot at the first grinding down, but thereafter remained uniform in quality. From 9 a. m. until noon, coal was charged once every 30 minutes, and after that at 45-minute intervals. The engine carried full load, but labored considerably.

Throughout the evening shift the producer was in excellent condition and gave a gas of uniformly good quality. The engine carried full load and worked well except for an occasional preignition in the right cylinder.

November 2: At the beginning of the morning shift the fuel bed fell several inches, due to the caving of an arch which had formed near its top. The fall broke the fuel bed up badly and caused the heat value of the gas to decrease about 20 B. t. u. per cubic foot, but the value was restored during the next 2 hours and ran uniformly at about 150 B. t. u. per cubic foot during the remainder of the shift. The engine ran satisfactorily under full load, but the varying heat value of the gas during the first part of the shift necessitated frequent changes of the air and gas valve settings.

Throughout the day shift the fuel bed was in good condition, yielding a gas with a heat value of 150 to 160 B. t. u. per cubic foot. After 11 a. m. coal, which was at least three-fourths slack, was charged once every 30 minutes. In the afternoon the ash bed was ground down a little at three different times without lowering the heat value of the gas to any great extent. The engine carried a steady full load and ran well except for a little difficulty with one of the igniters.

The fuel bed was in excellent condition during the entire evening shift. The gas was fairly uniform in quality and had an average heat value of about 150 B. t. u. per cubic foot. At 9 a. m. the ash bed was ground down without causing any noticeable effect in the heat value of the gas. The engine carried the regular load, but did not run as easily as usual, and throughout the shift the gas consumption was rather high, being about 6,500 cubic feet per 20 minutes.

November 3: The fuel bed was in fine working order and gave a gas of very uniform quality, although the ash bed was ground down four times during the morning shift. After 2.15 a. m. coal was charged once every 45 minutes. The engine carried a steady full load and required little attention.

During the day shift the fuel bed was in good condition and the heat value of the gas increased from 145 B. t. u. to about 160 B. t. u. per cubic foot. The ash bed was ground down twice. The engine carried a steady load and worked well except for a few back fires.

The engine ran steadily and carried a full load without difficulty throughout the evening shift. The producer worked satisfactorily and gave a gas of uniformly good quality.

November 4: The fuel bed was in excellent condition during the entire morning shift. At 2 a. m. the ash bed was ground down without impairing the quality of the gas. The engine ran well, with full load, and required little attention.

The fuel bed was a little low at the beginning of the day shift. After 8.30 a. m. coal was charged once every 30 minutes. The gas was fairly uniform in quality and had an average heat value of 150 B. t. u. per cubic foot. The engine ran steadily and carried full load without difficulty. At 10 a. m. the load was reduced about half for 2 minutes, during which time the igniter on the right cylinder was disconnected and a sample of the explosive mixture was taken from the cylinder. A sample of gas direct from the gas holder was also taken at the same time, and this operation of taking samples was repeated at 1.55 p. m. Analyses of these samples are given in the following table:

Analyses of samples of explosive mixtures and producer gas, test 168.

Samples taken—	Character of sample.	CO_2.	O_2.	C_2H_4.	CO.	H_2.	CH_4.	N_2.	B. t. u. per cubic foot.
Nov. 4—10 a. m.	Mixture	2.4	12	0	9.4	5.4	0.9	69.9	61.18
	Gas	7.2	0	0	24.2	13.8	2.1	52.7	154.8
Nov. 4—1.55 p. m.	Mixture	2.5	13.7	0	7.6	4.6	.9	70.7	52.11
	Gas	8.2	0	0	21.8	13.8	2.1	54.1	146.4
Nov. 5—1.55 p. m.	Mixture	3.5	10.6	[a]0.3	10.4	9.2	1.2	64.8	86.1
	Gas	7.5	0	0	22.8	15	1.8	52.9	150.9

[a] The C_2H_4 in the mixture was probably derived from oil which had leaked past the piston from the crank case.

At 3.15 p. m. the aperture admitting air to the blower was opened much wider, allowing a greater proportion of air to enter the blast.

Beginning with the evening shift the effect of the increased proportion of air in the blast was quite noticeable. The temperature of the gas leaving the producer fell about 50° F.; the CO_2 decreased 1 to 2 per cent, while the CO increased as much; and the heat value of the gas increased steadily throughout the shift, rising nearly 20 B. t. u. per cubic foot. The fuel bed was kept in excellent condition, with coal charged once every 45 minutes. The engine ran steadily and easily carried full load.

November 5: The fuel bed was in good working order during the entire morning shift and the gas was of good and fairly uniform quality. At 6 a. m. the ash bed was ground down, and the heat value of the gas fell about 15 B. t. u. per cubic foot. The coal was about three-fourths slack. The engine ran steadily and gave no trouble.

The fuel bed was in good condition and yielded a gas of uniform quality throughout the day shift. The engine ran steadily and carried full load without difficulty. At 1.55 p. m. the load was reduced by half for two minutes, while a sample of explosive mixture was taken from the left cylinder. Analyses of this sample and of a sample of gas from the gas holder taken at the same time are included in the table on page 252.

The producer worked exceptionally well from 4 p. m. to midnight, although the coal charged was mostly slack. The gas was of good quality and of uniform heat value. The engine ran satisfactorily and carried a steady full load.

November 6: During the morning shift the fuel bed was in good working order. The gas was of uniform quality and had an average heat value of about 160 B. t. u. per cubic foot. An accumulation of soot in the gas main leading to the scrubber slightly increased the pressure of the gas leaving the producer, but did not seriously impair the working of the producer. At 4.20 a. m. the ash bed was ground down. During the next hour the heat value of the gas decreased about 10 B. t. u. per cubic foot, but soon increased to normal. The coal charged during the shift was mostly slack. The engine carried full load and ran well except for a few premature ignitions in the right cylinder.

At the beginning of the day shift the producer was in good working order, yielding a gas of uniform heat value and of good quality. Temperature determinations at different points in the fuel bed were made throughout the day and gas samples for analysis were taken at the same points. This work interfered with uniform charging and the regular poking of the fuel bed. As a result the heat value of the gas fell several B. t. u. during the shift. The pressure of the gas leaving the producer was high, and gradually increased as soot collected in the pipe between the producer and scrubber. At 3 p. m. an attempt was made to clear this pipe. This operation generally had not proved very effective while the producer was in operation, but this attempt was quite successful, and within a short time the gas pressure was normal. At 3.20 p. m. the ash bed was ground down without seriously affecting the heat value of the gas. On account of the varying quality of the gas during the shift, the air and gas valve settings at the engine were changed frequently; and during the last part of the shift, when the heat value of the gas was rather low, there was difficulty in maintaining full load.

At the beginning of the evening shift the fuel bed was in rather poor condition, but after 5 p. m. coal was charged at 30-minute intervals and the fuel bed was poked regularly. The heat value of the gas increased steadily, and at 8 p. m. it was over 150 B. t. u. per cubic foot and the fuel bed was in good working order. About 9 p. m. one of the igniters caused trouble by sticking, and for a while the load was irregular. With this exception the engine carried a steady full load throughout the shift.

November 7: During the morning shift the fuel bed was rather thin and there was a tendency to form blowholes. The coal charged was nearly all slack. The gas was of good quality, but its heat value was rather variable, ranging from 150 B. t. u. to 164 B. t. u. per cubic foot. The engine ran steadily and carried full load.

Temperature and gas-sampling work on the fuel bed continued during the day shift and interrupted regularity in the care of the producer. The fuel bed, however, was not seriously affected and the quality of gas was more uniform than during the same work on the previous day. The engine ran satisfactorily.

During the entire evening shift the fuel bed was in good working order. Coal was charged once every 45 minutes, and the heat value of the gas increased 10 B. t. u. to 12 B. t. u. per cubic foot. The engine carried a steady full load.

November 8: Throughout the morning shift the producer was in excellent condition, yielding a gas with a heat value of about 160 B. t. u. per cubic foot. The engine carried full load, and except for a few preignitions it ran steadily and without difficulty. At 7 a. m. the injector on the auxiliary boiler gave out and steam for the producer was taken from the main boiler plant of the testing station. There was no way to determine the amount of this steam used.

The producer was in good working order at the beginning of the day shift. Although the determination of temperatures and the gas sampling were continued, the fuel bed was kept in good condition and the heat value of the gas was not seriously affected. The ash bed was ground down twice during the shift. The injector on the auxiliary boiler was repaired, and after 11.30 a. m. this boiler supplied the necessary steam. The centrifugal pump gave considerable trouble because of a leaky stuffing box, and city water was used much of the time. The engine ran satisfactorily and carried an average full load.

The fuel bed was in good working order and the gas had a uniform heat value of about 150 B. t. u. per cubic foot throughout the evening shift. The coal, mostly slack and rather dry and dusty, had a tendency to blow over into the scrubber. On this account the fuel was moistened during the greater part of the shift. The engine back fired several times and one of the igniters gave some trouble, but a steady full load was carried.

November 9: During the first part of the morning shift the fuel bed was in excellent condition and the gas was of good quality. At 4 a. m. the ash bed was ground down about 3 inches, and the fuel bed, which was rather thin, was broken up somewhat. The heat value of the gas, however, was not materially affected, although it decreased a little during the remainder of the shift. Coal, which was mostly slack, was charged every 45 minutes until 6 a. m., when the interval between charges was changed to 30 minutes. The engine ran smoothly and carried full load.

At the beginning of the day shift the fuel bed was in rather poor condition, being somewhat broken up and showing a tendency to form blowholes. The determination of temperatures and the taking of gas samples were continued. The condition of the fuel bed did not improve during the day, and the heat value of the gas was variable The engine carried an average full load and ran satisfactorily except for a few preignitions.

The fuel bed was not in good working order at the beginning of the evening shift, but care and extra poking soon brought it into a fairly good condition, which continued to improve throughout the rest of the test. The gas was of uniform heat value and of good quality. The engine ran satisfactorily and carried a steady full load. At midnight, after a continuous run of 240 hours, the test was brought to a close. At the end of the run the producer was in excellent working condition and the engine was running steadily with full load.

The proximate analysis of a sample of refuse from this test gave the following results (in per cent by weight): Moisture, 18.06; combustible, 4.30; ash, 77.64. The high percentage of moisture is due to the fact that the ashes were removed through the water seal. Graphic log is given on page 250.

JAMESTOWN No. 8.

Jamestown No. 8, test 169.—Test 169, for which a coal from Argentina, South America, was used, resulted in a failure. When delivered on the gas-producer platform the fuel contained a large proportion of very fine coal and was dry and dusty; what lumps there were appeared to be shale, and the mass as a whole looked not unlike a pile of dirt. A sample of the fuel taken during the test gave the following proximate analysis: Moisture, 8.67; volatile matter, 18.03; fixed carbon, 29.98; ash, 43.32; sulphur, 0.56 per cent. The heat value of the fuel as fired was 6,017 B. t. u. per pound.

The first charge of Argentina coal was made about 7 a. m. upon the fuel bed of West Virginia coal remaining in the producer after test 168. The next few charges were made at hourly intervals.

The engine was started at 10.50 a. m. at nearly full load and on gas with a heat value of about 150 B. t. u. per cubic foot. However, this gas came almost entirely from the West Virginia coal and there was a marked change as the proportion of Argentina coal in the fuel bed increased. About noon the heat value of the gas began to diminish rapidly, and at 5.30 p. m. the consequent decrease in speed of the engine was noticeable, but the engine continued to run at gradually decreasing speed and with no load until 7.45 p. m., when it stopped.

In order to maintain the proper thickness of fuel bed it was necessary to increase continually the rate of charging. At the beginning of the test a charge of 150 pounds was made once an hour, while at the time the engine stopped a charge was being made every 10 minutes, and even then the thickness of fuel bed was decreasing.

The next morning several unsuccessful attempts were made to start the engine, but the gas was too poor and would not even burn at the producer. By firing this Argentina coal under the auxiliary boiler it was possible to keep up sufficient steam for the producer, but to do this required the undivided attention of one man, and it was also necessary to pick the coal, using only the lumps. Ordinarily, the auxiliary boiler required but little attention.

The fact that this fuel contained a large proportion of slack was largely responsible for its failure in the gas producer. It packed together, making a uniform distribution of the blast impossible. This coal might work satisfactorily when freshly mined.

The following table gives the significant observations made during the test:

Observed data of producer-gas test 169.

Coal charged.		Time of observation.	Load.		B. t. u. by calorimeter	Volumetric gas analysis (per cent).					Calculated B. t. u.
Time.	Pounds.		Volts.	Amperes		CO_2.	CO.	H_2.	CH_4.	N.	
12.00 m.	150	12.00 m.	238	550	148.0	6.0	26.8	10.8	1.8	54.6	150.2
12.30 p. m.	150	12.20 p. m.	236	565	146.5	......	......	......	......	......	......
1.00 p. m.	150	12.40 p. m.	238	545	145.0	......	......	......	......	......	......
1.20 p. m.	150	1.00 p. m.	238	585	141.5	......	......	......	......	......	......
1.40 p. m.	150	1.20 p. m.	236	575	138.0	......	......	......	......	......	......
2.40 p. m.	150	1.40 p. m.	239	540	141.5	......	......	......	......	......	......
2.20 p. m.	150	2.00 p. m.	238	500	138.9	7.3	24.4	9.8	1.8	56.7	138.4
3.00 p. m.	150	2.20 p. m.	230	545	132.0	......	......	......	......	......	......
3.20 p. m.	150	2.40 p. m.	234	545	138.0	......	......	......	......	......	......
3.40 p. m.	150	3.00 p. m.	238	300	135.0	......	......	......	......	......	......
4.00 p. m.	300	3.20 p. m.	238	270	134.5	......	......	......	......	......	......
4.20 p. m.	150	3.40 p. m.	234	400	128.5	......	......	......	......	......	......
4.40 p. m.	150	4.00 p. m.	242	400	126.0	8.6	21.6	7.8	1.2	60.8	115.3
5.00 p. m.	300	4.20 p. m.	240	400	120.0	......	......	......	......	......	......
5.20 p. m.	150	4.40 p. m.	240	300	125.0	......	......	......	......	......	......
5.35 p. m.	150	5.00 p. m.	240	300	121.0	......	......	......	......	......	......
5.50 p. m.	150	5.20 p. m.	230	300	107.5	......	......	......	......	......	......
6.00 p. m.	150	5.40 p. m.	240	200	94.5	......	......	......	......	......	......
6.10 p. m.	150	6.00 p. m.	230	200	68.0	12.0	13.9	6.8	.6	66.7	73.8
6.20 p. m.	150	6.20 p. m.	235	200	48.5	......	......	......	......	......	......
6.30 p. m.	150	6.40 p. m.	235	200	45.2	......	......	......	......	......	......
6.40 p. m.	150	7.00 p. m.	240	200	......	......	......	......	......	......	......
6.50 p. m.	150	7.20 p. m.	240	200	......	......	......	......	......	......	......
7.05 p. m.	150	7.40 p. m.	210	50	......	......	......	......	......	......	......

EXPLANATION OF ITEMS IN TABLES OF RESULTS.

In order that the meaning of the items given in the tables of results (pp. 272–313 and 352–358) may be clear, the following list is given, explaining each item and the method of deriving the results when computations are involved.

GENERAL DESCRIPTIVE ITEMS.

Item 1. Test number.—For convenience the tests are numbered in consecutive order as they are made.

Item 2. Designation of fuel.—In keeping records each fuel is given a name and number by which it is designated. Example (test No. 140): Pennsylvania No. 13.

Item 3. Name of bed.—This is a name or number given to the coal seam by State surveys or mine operators, and in some cases has only a local significance.

Item 4. Location of mine or deposit.—Under this item is given the name of the town in which the mine or deposit is situated, or, in some cases, the name of the nearest town.

Item 5. Duration of test (hours).—Item 5 gives the length of test upon which the report is based.

Items 6, 7, 8, 9, and 10. Size of fuel.—In many of the tests the fuel was sampled and sized. These items give the sizes and the percentage by weight of each size in the sample.

PROXIMATE ANALYSIS OF FUEL AS FIRED (PER CENT).

The following items, which state the results of the separate determinations, are self-explanatory:

Item 11. Moisture;
Item 12. Volatile matter;
Item 13. Fixed carbon;
Item 14. Ash;
Item 15. Sulphur (separately determined).

A sample of the fuel was collected during each test by taking a small quantity from each charge fed the producer. From this sample a proximate analysis was made. The results given under these items are taken from the chemist's reports.

TOTAL FUEL CHARGED IN PRODUCER (POUNDS).

Item 16. As fired.—For the tests made at St. Louis and Norfolk this item gives the total coal consumed as calculated after making corrections due to changes in thickness of the fuel bed, which frequently take place during a test. Example: The total coal charged during a test was 12,600 pounds and the fuel bed decreased in thickness 8 inches. A layer of coal 8 inches thick in the producer used is equivalent to approximately 1,200 pounds. Therefore, the total coal consumed was $12,600+1,200=13,800$ pounds. Similarly, if the fuel bed increased in thickness 8 inches, the total coal consumed would be $12,600-1,200=12,400$ pounds. (For a further discussion of changes in fuel bed thickness and methods of measuring the fuel bed, see Bull. 393, U. S. Geological Survey.) In the tests made at the Pittsburg station item 16 included the fuel equivalent of the coke consumed during the test. (See item 36.)

Example: Total coal charged during test, 16,000 pounds; coke consumed, 450 pounds; heat value of the coke, 12,220 B. t. u. per pound; heat value of the coal, 11,400 B. t. u. per pound. The fuel equivalent of the coke consumed is then $\frac{450\times 12{,}220}{11{,}400}=482$ pounds, and the total fuel consumed during the test is $16{,}000+482=16{,}482$ pounds.

Item 17. Dry.—This item is calculated from item 16 by deducting the percentage of moisture as determined by the proximate analysis. Item $17=\frac{\text{item } 16\times(100-\text{item } 11)}{100}$.

Example (test No. 176): $\frac{16{,}670\times(100-1.37)}{100}=16{,}442$ pounds.

Item 18. Refuse (determined from analysis).—In the tests at St. Louis and Norfolk there was little if any unburned coal in the ash deposited at the base of the producer. Owing to the depth of ash bed in the producer, the ash from any given fuel was not available for inspection until several days after the fuel had been fired. Although sufficient time was allowed for the complete consumption of a previously fired fuel before beginning the test of another fuel, yet the different fuels charged followed each other with such rapidity that the ash bed was, of necessity, made up of the refuse from several different fuels. The amount of unburned fuel passing through the producer was so small that the percentage of refuse could be taken, without great error, from the proximate analysis. The total refuse for these tests was calculated from the total fuel fired and the per cent of ash shown by the proximate analysis. Item $18=\frac{\text{item } 16\times\text{item } 14}{100}$.

Example (test No. 140): $\frac{11{,}750\times .1207}{100}=1{,}418$ pounds.

In the Pittsburg tests this item, although not given in the table, has been used in calculating the total combustible charged.

Item 19. Refuse (determined by weight).—In the tests made at the Pittsburg station all refuse was removed from the producer at the end of each test and weighed, and in these tests the refuse contained a considerable amount of combustible.

Item 20. Combustible.—Item 20 = item 17 − item 18.

Example (test No. 140): $11{,}550-1{,}418=10{,}132$ pounds.

FUEL CHARGED IN PRODUCER PER HOUR (POUNDS).

Item 21. *As fired.*—Item 21 = item 16 ÷ item 5.

Example (test No. 140): $\frac{11,750}{50} = 235$ pounds.

Item 22. *Dry.*—Item 22 = item 17 ÷ item 5.

Example (test No. 140): $\frac{11,550}{50} = 231$ pounds.

Item 23. *Combustible.*—Item 23 = item 20 ÷ item 5.

Example (test No. 140): $\frac{10,132}{50} = 202.6$ pounds.

FUEL CHARGED IN PRODUCER PLANT PER HOUR (POUNDS).

Item 24. *As fired.*—
Item 25. *Dry.*—
Item 26. *Combustible.*—

The fuel charged in the producer plant includes both the fuel charged in the producer and the fuel equivalent of the steam required for operating the producer. In the tests at St. Louis steam for the producer blower was obtained from the boiler plant, and the quantity used was determined approximately from the steam pressures recorded during the tests and from calibrations made under varying pressures of the steam nozzles which delivered the steam to the producer blower. The number of pounds of fuel per hour equivalent to the steam consumed by the producer was obtained by dividing the number of pounds of steam used per hour by the number of pounds of water actually evaporated in the boiler plant by each pound of the fuel used for the producer-gas test under consideration.

As nearly all of the fuels tested in the producer were also tested under the boilers, and as the steam for the producer blast was furnished by these same boilers, the evaporation factor has been taken directly from the records of the steam tests.

In case no steam test was made with fuel of the same kind as that used in the producer, the fuel equivalent of the steam used was determined either by comparison of the chemical analysis of the fuel with that of a similar fuel, or by assuming an average value for the fuel equivalent. In the tests made at Norfolk a small auxiliary boiler supplied steam for the producer. A record was kept of coal required for this boiler, and for the Norfolk tests items 24, 25, and 26 include the fuel charged in the producer and also the fuel used by the auxiliary boiler.

FUEL CHARGED PER SQUARE FOOT OF FUEL-BED AREA PER HOUR (POUNDS).

Item 27. *As fired.*—Item 27 = item 21 ÷ area of fuel bed in square feet. The producer used in St. Louis and Norfolk was 7 feet in internal diameter, thus giving a fuel bed with an area of 38.48 square feet. In the producer used at Pittsburg this area was 12.96 square feet.

Example (test No. 140): $\frac{235}{38.48}=6.1$ pounds.

Item 28. Dry.—Item 28 = item 22 ÷ area of fuel bed in square feet.

Example (test No. 140): $\frac{231}{38.48}=6.0$ pounds.

Item 29. Combustible.—Item 29 = item 23 ÷ area of fuel bed in square feet.

Example (test No. 140): $\frac{202.6}{38.48}=5.3$ pounds.

COMBUSTIBLE IN REFUSE.

Item 30. Total combustible in refuse (pounds).—When the refuse from the Pittsburg tests was removed from the producer the clinker was separated; the remainder of the refuse was then sampled and a proximate analysis made. The total combustible in the refuse as given in item 30 is based upon the weight of refuse, excluding the clinker, and the percentage of combustible taken from the analysis of this refuse, it being assumed that there was little, if any, combustible in the clinker.

Item 31. Per cent combustible in refuse.—Item 31 = $\frac{\text{item } 30}{\text{item } 19}\times 100$.

Example (test No. 176): $\frac{736}{2{,}731}\times 100=26.9$ per cent.

COMBUSTIBLE CONSUMED.

Item 32. Total combustible consumed (pounds).—Item 32 = item 20 ÷ item 30.

Example (test No. 176): $14{,}533-736=13{,}797$ pounds.

Item 33. Per cent of total combustible consumed.—Item 33 = $\frac{\text{item } 32}{\text{item } 20}\times 100$.

Example (test No. 176): $\frac{13{,}797}{14{,}533}\times 100=94.9$ per cent.

In the Pittsburg tests a layer of coke was used in building up the initial fuel bed. At the end of each test all coke that could be used again was separated from the refuse and weighed.

COKE IN FIXING BED (POUNDS).

Item 34. Total charged in producer.—
Item 35. Recovered from refuse.—
Item 36. Consumed during test.—
Item 36 = item 34 − item 35.
Example (test No. 188): $1{,}118-817=301$ pounds.

CALORIFIC VALUE OF FUEL (BRITISH THERMAL UNITS PER POUND).

Item 37. As fired.—This value is taken from the chemist's report.

Item 38. Dry.—This value is taken from the chemist's report.

Item 39. Combustible.—This value is taken from the chemist's report.

Item 40. British thermal units per hour from fuel as fired.—Item 40 = item 21 × item 37.

Example (test No. 140): 235 × 13,181 = 3,099,000 B. t. u.

CALORIFIC VALUE (BRITISH THERMAL UNITS) OF STANDARD GAS (62° F. AND 14.7 POUNDS PRESSURE).

Item 41. From 1 pound of fuel as fired.—Item 41 = item 43 × item 54.

Example (test No. 140): 144.9 × 75.2 = 10,900 B. t. u.

Item 42. From 1 pound of dry fuel.—Item 42 = item 43 × item 55.

Example (test No. 140): 144.9 × 76.5 = 11,100 B. t. u.

Item 43. Per cubic foot.—The calorific power of the gas has been determined by means of a Junker's calorimeter and the readings corrected to standard pressure and temperature. The high heat value has been used at all times. In a few of the tests the calorimeter was not used, owing to clogging of the small gas meter; in these tests the heat value of the gas has been calculated from the analysis. Item 43 gives the average of all values obtained during a test.

CALORIFIC VALUE OF STANDARD GAS CONSUMED PER HORSEPOWER HOUR (BRITISH THERMAL UNITS).

Item 44. Indicated.—Item 44 = item 43 × item 61.

Example (test No. 176): 118.9 × 77.4 = 9,203 B. t. u.

Item 45. Brake.—Item 45 = item 43 × item 62.

Example (test No. 176): 118.9 × 90.4 = 10,749 B. t. u.

Item 46. Electrical.—Item 46 = item 43 × item 63.

Example (test No. 176): 118.9 × 104.6 = 12,437 B. t. u.

BRITISH THERMAL UNITS EQUIVALENT TO STATED HORSEPOWER PER MINUTE.

The heat equivalent per minute of the power developed is here given in British thermal units based upon the mechanical equivalent of heat, or 42.4 B. t. u. per horsepower per minute.

Item 47. Gas.—Item 47 = item 103 × 42.4.

Example (test No. 176): 591 × 42.4 = 25,070 B. t. u. (For an explanation of gas horsepower see item 103.)

Item 48. Indicated.—Item 48 = item 118 × 42.4.

Example (test No. 176): 163.4 × 42.4 = 6,931 B. t. u.

Item 49. Brake.—Item 49 = item 119 × 42.4.

Example (test No. 176): 139.8 × 42.4 = 5,930 B. t. u.

Item 50. Electrical.—Item 50 = item 121 × 42.4.

Example (test No. 176): 120.8 × 42.4 = 5,124 B. t. u.

GAS PRODUCTION.

Item 51. Gas produced per hour (cubic feet).—This item gives the volume of gas produced as determined by meter and without correction to standard conditions of temperature and pressure. The item does not include the gas used by the calorimeter and gas sampling apparatus, which was approximately 10 cubic feet per hour.

Item 52. Total standard gas produced (cubic feet).—Since a definite weight of gas varies in volume with a change in temperature or pressure, it becomes necessary to use standard conditions to which volumetric measurements of gas may be referred in order to make results comparable. For these standard conditions, 62° F. and 14.7 pounds pressure have been adopted.

The total gas output of the producer used during these tests consists of the gas passed through the main meter plus that used for the calorimeter and for gas sampling. The gas meter was read every 20 minutes throughout each test, and each reading was separately reduced to the corresponding value for standard gas by the formula $\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}$, in which P_1 is the actual pressure of the gas passing through the meter as determined by the barometer and a manometer; V_1, the volume of the gas as read by the meter plus 10 cubic feet per hour used for calorimetric work; T_1, the absolute temperature of the gas entering meter; P_2, the standard pressure (14.7 pounds); and T_2, the standard absolute temperature (521° F.). V_2 is the required standardized volume of gas. The formula may be put in the form $V_2=V_1\times\frac{T_2}{P_2}\times\frac{P_1}{T_1}$, in which $\frac{T_2}{P_2}$ is readily seen to be a constant, and the formula becomes $V_2=V_1\times K\times\frac{P_1}{T_1}$.

Example: Given—gas used by engine and calorimeter for one 20-minute period, 4,890 cubic feet; temperature of gas entering meter, 72° F.; and pressure of gas entering meter, 14.825 pounds per square inch; required—the volume of standard gas.

$$V_1=4{,}890.$$
$$P_1=14.825.$$
$$T_1=459+72=531^\circ \text{ F.}$$
$$T_2=459+62=521^\circ \text{ F.}$$
$$P_2=14.7.$$
$$K=\frac{T_2}{P_2}=\frac{521}{14.7}=35.44.$$
$$V_2=4{,}890\times 35.44\times\frac{14.825}{531}=4{,}835 \text{ cubic feet.}$$

Item 53. Standard gas produced per hour (cubic feet).—Item 53 = item 52 ÷ item 5.

Example (test No. 176): $\frac{1{,}315{,}731}{104}=12{,}651$ cubic feet.

Standard gas produced per pound of fuel charged in producer (cubic feet).

Item 54. As fired.—Item 54 = item 53 ÷ item 21.

Example (test No. 176): $\frac{12,651}{160.3} = 78.9$ cubic feet.

Item 55. Dry.—Item 55 = item 53 ÷ item 22.

Example (test No. 176): $\frac{12,651}{158.1} = 80$ cubic feet.

Item 56. Combustible.—Item 56 = item 53 ÷ item 23.

Example (test No. 176): $\frac{12,651}{139.7} = 90.6$ cubic feet.

Standard gas produced per pound of total fuel used by producer.

Item 57. As fired.—Item 57 = item 53 ÷ item 24.

Example (test No. 140): $\frac{17,680}{255.8} = 69.2$ cubic feet.

Item 58. Dry.—Item 58 = item 53 ÷ item 25.

Example (test No. 140): $\frac{17,680}{251.5} = 70.3$ cubic feet.

Item 59. Combustible.—Item 59 = item 52 ÷ item 26.

Example (test No. 140): $\frac{17,680}{220.6} = 80.1$ cubic feet.

GAS CONSUMPTION.

Item 60. Standard gas consumed by engine per hour (cubic feet).—Item 60 = item 53 − 10 cubic feet used by the calorimeter.

Standard gas consumed per horsepower hour (cubic feet).

Item 61. Indicated.—Item 61 = item 60 ÷ item 118.

Example (test No. 176): $\frac{12,641}{163.4} = 77.4$ cubic feet.

Item 62. Brake.—Item 62 = item 60 ÷ item 119.

Example (test No. 176): $\frac{12,641}{139.8} = 90.4$ cubic feet.

Item 63. Electrical.—Item 63 = item 60 ÷ item 121.

Example (test No. 176): $\frac{12,641}{120.8} = 104.6$ cubic feet.

COMPOSITION OF GAS (PER CENT OF VOLUME).

Item 64. Carbon dioxide (CO_2).—
Item 65. Oxygen (O_2).—
Item 66. Ethylene (C_2H_4).—
Item 67. Carbon monoxide (CO).—
Item 68. Hydrogen (H_2).—
Item 69. Methane (CH_4).—
Item 70. Nitrogen (N_2).—

The values given in items 64 to 70, inclusive, are taken from the chemist's report. These results are an average of all the gas analyses made during the test.

WATER USED IN VAPORIZER.

Item 71. Total water used in vaporizer (*pounds*).—In the tests made at Pittsburg, steam for the producer was formed in the economizer, or, as it is here called, the vaporizer. Water for this purpose was supplied from a graduated tank through a valve regulated to adjust the rate of flow; the quantity of water used was observed and recorded hourly. From these records the results given in item 71 are taken. (For a description of this tank, see p. 317.)

Item 72. Water used in vaporizer per hour (*pounds*).—Item 72 = item 71 ÷ item 5.

Example (test No. 176): $\frac{5,317}{104} = 51.1$ pounds.

Item 73. Water used in vaporizer per pound of fuel fired (*pounds*).—In the Pittsburg tests this item is equal to item 72 ÷ item 21.

Example (test No. 176): $\frac{51.1}{160.3} = 0.32$ pound.

Water used by producer plant (*cubic feet*).

Item 74. Total.—
Item 75. Per hour.—
Item 76. Producer top, per hour.—
Item 77. Scrubber, per hour.—
Item 78. Tar extractor, per hour.—
Item 79. Per 1,000 cubic feet of standard gas produced.—
Item 80. Per horsepower of producer plant.—

Water used in engine jackets (*cubic feet*).

Item 81. Total.—
Item 82. Per hour.—
Item 83. Per brake-horsepower hour.—

Water used by producer plant and engine combined (*cubic feet*).

Item 84. Total.—
Item 85. Per hour.—
Item 86. Per brake-horsepower hour.—

The items on water consumption have been taken from water-meter readings which were made at frequent intervals during each test.

AVERAGE PRESSURES.

Item 87. Barometric (*inches of mercury*).—The barometric pressures were used in standardizing the gas. Sometimes these readings were obtained from the local weather bureau; at other times they were taken from readings of the barometer used at the testing station.

Item 87 gives the average of all readings taken during the test, but in the computations this average is not used. In standardizing the gas a test was divided into several periods, and the gas for each period was corrected by the barometric reading corresponding to that period. The pressure of the gas entering the meter is measured in inches of water by a manometer, and this reading is used in connection with the barometric reading in standardizing the gas.

Item 88. Air and steam entering producer (inches of water).—

Item 89. Gas leaving producer (inches of water).—

Item 90. Gas leaving economizer (inches of water).—

Item 91. Gas leaving wet scrubber (inches of water).—

Item 92. Gas entering dry scrubber (inches of water).—

Item 93. Gas entering meter (inches of water).—

Item 94. Gas leaving meter (inches of water).—

The figures given in items 88 to 94, inclusive, are the average of all readings taken during the test. In each case the pressure is measured by means of manometers.

Average temperatures (°F.).

Item 95. Air entering economizer.—

Item 96. Air and steam entering producer.—

Item 97. Gas leaving producer.—

Item 98. Gas leaving economizer.—

Item 99. Gas leaving wet scrubber.—

Item 100. Gas entering meter.—

Item 101. Water entering engine jackets.—

Item 102. Water leaving engine jackets.—

The temperature of the gas leaving the producer (item 97) was measured by means of a thermocouple connected to a galvanometer. In the tests at St. Louis and Norfolk a tube containing the thermocouple was inserted in the top of the economizer and directly in the path of the gases leaving the producer. At the Pittsburg plant the tube was inserted in the gas connection between the producer and the economizer. Temperature readings were made from the galvanometer every hour. All other temperatures given were read from thermometers of a standard make.

GENERAL ENGINE DATA.

Item 103. Gas horsepower.—Gas horsepower is the mechanical equivalent, expressed in horsepower units, of the heat value of the gas produced. One British thermal unit being equivalent to 778 foot-pounds, the heat equivalent of 1,980,000 foot-pounds [a] is 2,545 B. t. u., and when gas is produced at such a rate that its total heat value per hour is equal to 2,545 B. t. u. it may be termed a gas horsepower. Gas horsepower is, then, equal to the total heat value of the gas produced per hour expressed in British thermal units divided by 2,545.

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[a] 1,980,000 foot-pounds per hour equal 1 horsepower.

$$\text{Item } 103 = \frac{\text{item } 53 \times \text{item } 43.}{2{,}545}$$

$$\text{Example (test No. 176): } \frac{12{,}641 \times 118.9}{2{,}545} = 591 \text{ gas horsepower.}$$

Item 104. Revolutions per minute of gas engine.—This item was determined by revolution counters attached to the engine.

Item 105. Explosions per minute per cylinder.—No method of counting explosions has been used, and the number of explosions for each cylinder has been taken as half the number of revolutions, as the number of misfires was negligible.

The items giving indicator card pressures are averages of cards taken during the test. The area of all cards was determined by means of a planimeter, and the mean effective pressure was found by dividing the area in square inches by the length in inches and multiplying by the scale per inch of the spring. The indicated horsepower was then figured for each cylinder of the engine according to the usual formula: $\text{Horsepower} = \frac{\text{PLAN}}{33{,}000.}$

In the Pittsburg tests the indicated horsepower was taken from a curve, for a discussion and explanation of which see page 324.

INDICATOR CARD PRESSURES (POUNDS PER SQUARE INCH).

Maximum.

Item 106. First cylinder.—
Item 107. Second cylinder.—
Item 108. Third cylinder.—

At release.

Item 109. First cylinder.—
Item 110. Second cylinder.—
Item 111. Third cylinder.—

Mean effective pressure.

Item 112. First cylinder.—
Item 113. Second cylinder.—
Item 114. Third cylinder.—

INDICATED HORSEPOWER.

Item 115. First cylinder.—
Item 116. Second cylinder.—
Item 117. Third cylinder.—
Item 118. Total.—

Item 118 is the sum of items 115, 116, and 117.

BRAKE HORSEPOWER.

Item 119. Brake horsepower developed at engine.—In the tests made at St. Louis and Norfolk this item is based upon the electrical horsepower developed, with an assumed efficiency of 85 per cent for the generator and belt. Item 119 = item 121 ÷ 0.85.

Example (test No. 140): $\frac{196.5}{.85} = 231.2$ brake horsepower.

In the Pittsburg tests an efficiency load curve for the generator was secured, and this was combined with an assumed efficiency of 96 per cent for the belt. The brake horsepower was then determined as in the St. Louis and Norfolk tests.

Item 120. Brake horsepower commercially available.—By brake horsepower commercially available is meant the brake horsepower developed by the engine less the equivalent brake horsepower necessary for the operation of the auxiliary machinery of the plant. It bears the same ratio to brake horsepower developed that the electrical horsepower commercially available bears to the electrical horsepower developed. Item 120 = item 119 × item 122 ÷ item 121.

Example (test No. 140): $\frac{231.2 \times 188.2}{196.5} = 221.4$ brake horsepower commercially available.

ELECTRICAL HORSEPOWER.

Item 121. Electrical horsepower developed at switchboard.—Throughout each test the voltmeter and ammeter were read every 20 minutes. Each 20-minute reading was reduced to its equivalent horsepower by the following rule: $\frac{\text{volts} \times \text{amperes}}{746} = \text{electrical horsepower}$.

The average of these values for the entire test is given in item 121.

Item 122. Electrical horsepower commercially available.—This item is equal to the electrical horsepower developed less the electrical horsepower required to drive the auxiliary machinery of the plant. (See item 123.) Item 122 = item 121 − item 123.

Example (test No. 140): $196.5 - 8.3 = 188.2$ electrical horsepower commercially available.

Item 123. Average electrical horsepower required to run the auxiliary machinery.—In the tests made at St. Louis and Norfolk power was used to drive the tar extractor, and in the Pittsburg tests to run the exhauster and gas compressor. This auxiliary machinery was motor driven, and the electrical current required was measured by means of a wattmeter, from which readings were taken hourly; the current thus required is given in item 123 as electrical horsepower.

ECONOMIC RESULTS.

Pounds of fuel per horsepower hour are given in items 124 to 150, inclusive. Items 124 to 138, inclusive, give the fuel consumed in the producer per horsepower hour, while items 139 to 150, inclusive, give the total fuel consumption of the plant, which includes the fuel charged in the producer and also the fuel required for the generation of the steam used.

FUEL CHARGED IN PRODUCER PER HORSEPOWER HOUR (POUNDS.)

Per indicated horsepower developed.

Item 124. *As fired.*—Item 124 = item 21 ÷ item 118.
Item 125. *Dry.*—Item 125 = item 22 ÷ item 118.
Item 126. *Combustible.*—Item 126 = item 23 ÷ item 118.

Per brake horsepower developed at engine.

Item 127. *As fired.*—Item 127 = item 21 ÷ item 119.
Item 128. *Dry.*—Item 128 = item 22 ÷ item 119.
Item 129. *Combustible.*—Item 129 = item 23 ÷ item 119.

Per brake horsepower commercially available.

Item 130. *As fired.*—Item 130 = item 21 ÷ item 120.
Item 131. *Dry.*—Item 131 = item 22 ÷ item 120.
Item 132. *Combustible.*—Item 132 = item 23 ÷ item 120.

Per electrical horsepower developed at switchboard.

Item 133. *As fired.*—Item 133 = item 21 ÷ item 121.
Item 134. *Dry.*—Item 134 = item 22 ÷ item 121.
Item 135. *Combustible.*—Item 135 = item 23 ÷ item 121.

Per electrical horsepower commercially available.

Item 136. *As fired.*—Item 136 = item 21 ÷ item 122.
Item 137. *Dry.*—Item 137 = item 22 ÷ item 122.
Item 138. *Combustible.*—Item 138 = item 23 ÷ item 122.

TOTAL FUEL CONSUMED BY PLANT PER HORSEPOWER HOUR (POUNDS).

Per brake horsepower developed at engine.

Item 139. *As fired.*—Item 139 = item 24 ÷ item 119.
Item 140. *Dry.*—Item 140 = item 25 ÷ item 119.
Item 141. *Combustible.*—Item 141 = item 26 ÷ item 119.

Per brake horsepower commercially available.

Item 142. *As fired.*—Item 142 = item 24 ÷ item 120.
Item 143. *Dry.*—Item 143 = item 25 ÷ item 120.
Item 144. *Combustible.*—Item 144 = item 26 ÷ item 120.

Per electrical horsepower developed at switchboard.

Item 145. *As fired.*—Item 145 = item 24 ÷ item 121.
Item 146. *Dry.*—Item 146 = item 25 ÷ item 121.
Item 147. *Combustible.*—Item 147 = item 26 ÷ item 121.

Per electrical horsepower commercially available.

Item 148. *As fired.*—Item 148 = item 24 ÷ item 122.
Item 149. *Dry.*—Item 149 = item 25 ÷ item 122.
Item 150. *Combustible.*—Item 150 = item 26 ÷ item 122.

STEAM USED BY PRODUCER (POUNDS).

Item 151. *Total.*—In the tests made at Norfolk steam was furnished for the operation of the producer from a small upright boiler. Care was taken to prevent any waste of steam by its blowing through the safety valve or otherwise, and the water consumption of the boiler during a test is taken as the total steam consumed. In the tests at St. Louis the amount of steam used was calculated from a record of pressures and calibrations of the steam nozzle. (See discussion following item 26.)

Item 152. *Per hour.*—Item 152 = item 151 ÷ item 5.

Example (test No. 140): $\frac{7700}{50} = 154$ pounds.

FUEL EQUIVALENT OF STEAM USED PER HOUR (POUNDS).

In the Norfolk tests these items are taken directly from the coal record of the auxiliary boiler, while for the St. Louis tests they are calculated from the steam consumption. (See discussion following item 26.)

Item 153. *As fired.*—
Item 154. *Dry.*—
Item 155. *Combustible.*—

EFFICIENCY (PER CENT).

Item 156. *Of conversion and cleaning gas.*—Item 156 is based upon the heat value of the coal consumed per hour and the heat value of the gas produced per hour after being cooled and cleaned.

$$\text{Item } 156 = \frac{\text{item } 53 \times \text{item } 43.}{\text{item } 21 \times \text{item } 37}$$

Example (test No. 176): $\frac{12{,}651 \times 118.9}{160.3 \times 13{,}725} = 68.4$ per cent.

Item 157. Of producer plant.—In the tests made at St. Louis and Norfolk this item is based upon the total fuel consumed by the plant per hour and the heat value of the gas after deducting the heat equivalent of the auxiliary power.

$$\text{Item } 157 = \frac{(\text{item } 53 \times \text{item } 43) - (2{,}545 \times \text{item } 123)}{\text{item } 24 \times \text{item } 37}$$

Example (test No. 140): $\frac{(17{,}680 \times 144.9) - (2{,}545 \times 8.3)}{255.8 \times 13{,}181} = 75.5$ per cent.

In the Pittsburg tests this item takes into account the power required to drive the auxiliary machinery, basing the efficiency upon the heat value of the gas after deducting the heat equivalent of the auxiliary power.

$$\text{Item } 157 = \frac{(\text{item } 53 \times \text{item } 43) - (2{,}545 \times \text{item } 123)}{\text{item } 21 \times \text{item } 37}$$

Example (test No. 176): $\frac{(12{,}651 \times 118.9) - (2{,}545 \times 3.2)}{160.3 \times 13{,}725} = 68$ per cent.

THERMAL EFFICIENCY OF ENGINE BASED UPON THE HEAT EQUIVALENT OF STATED HORSEPOWER DEVELOPED AND GAS HORSEPOWER.

Item 158. Indicated.—Item 158 = item 48 ÷ item 47.

Example (test No. 176): $\frac{6{,}931}{25{,}070} = 27.6$ per cent.

Item 159. Brake.—Item 159 = item 49 ÷ item 47.

Example (test No. 176): $\frac{5{,}930}{25{,}070} = 23.7$ per cent.

Item 160. Electrical.—Item 160 = item 50 ÷ item 47.

Example (test No. 176): $\frac{5{,}124}{25{,}070} = 20.4$ per cent.

EFFICIENCY OF ENTIRE PLANT, BASED ON THE HEAT EQUIVALENT OF ONE HORSEPOWER HOUR AND THE HEAT VALUE OF THE FUEL CONSUMED PER STATED HORSEPOWER PER HOUR.

Item 161. Brake horsepower developed at engine.—Item 161 = $\frac{\text{heat equivalent of 1 horsepower hour}}{\text{item } 127 \times \text{item } 37}$

Example (test No. 176): $\frac{2{,}545}{1.15 \times 13{,}725} = 16.1$ per cent.

Item 162. Brake horsepower commercially available.—Item 162 = $\frac{\text{heat equivalent of 1 horsepower hour}}{\text{item } 130 \times \text{item } 37}$

Example (test No. 176): $\frac{2{,}545}{1.18 \times 13{,}725} = 15.7$ per cent.

Item 163. Electrical horsepower developed at switchboard.—Item 163 = $\frac{\text{heat equivalent of 1 horsepower hour}}{\text{item } 133 \times \text{item } 37}$

Example (test No. 176): $\frac{2{,}545}{1.33 \times 13{,}725} = 13.9$ per cent.

Item 164. Electrical horsepower commercially available.—For the Pittsburg tests item 164 $= \frac{\text{heat equivalent of 1 horsepower hour}}{\text{item 136} \times \text{item 37}}$

Example (test No. 176): $\frac{2{,}545}{1.36 \times 13{,}725} = 13.6$ per cent.

In the tests made at St. Louis and Norfolk item 164 =

$$\frac{\text{heat equivalent of 1 horsepower hour}}{\text{item 148} \times \text{item 37}}$$

Example (test No. 140): $\frac{2{,}545}{1.36 \times 13{,}181} = 14.2$ per cent.

TAR.

In many of the tests made at St. Louis and Norfolk the tar produced was collected and weighed. The tar was washed from the gas, and it generally contained a high percentage of water, which was not easily separated. In a number of tests, however, the tar thus collected was placed in a steam heater, provided for the purpose, by means of which the greater part of the water in the tar was driven off.

Item 165. Pounds of tar per ton of fuel, water extracted.—This item was found by dividing the weight of tar produced for the entire test, after the water had been driven off by evaporation, by the weight, in tons, of the fuel consumed in the producer.

Item 166. Pounds of tar per ton of fuel, water not extracted.—This item was found by dividing the weight of tar as collected by the weight, in tons, of the fuel consumed in the producer.

SUPPLEMENTARY DATA.

Item 167. Remarks.—This item refers to the page upon which will be found a brief description of each test.

Results of producer-gas tests made at St. Louis and Norfolk.

Test No.	Designation of fuel.	Origin of fuel sample.		Duration of test (hours).	Size of fuel.					Proximate analysis of fuel as fired (per cent).					Total fuel charged in producer (pounds).			
		Name of bed.	Location of mine or deposit.		As shipped.	As used (per cent).				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur (separately determined).	As fired.	Dry.	Combustible.	Refuse (determined from analysis).
						Under ¼ inch.	¼ to ½ inch.	½ to 1 inch.	Over 1 inch.									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	20	18
	Alabama:																	
2	No. 2	Jagger	Carbon Hill	43	Over ¾ inch	....	....	....	....	3.76	33.45	53.29	9.50	0.86	13,350	12,848	11,580	1,268
109	No. 4	Youngblood	Belle Ellen	24	Run of mine	....	....	....	....	3.05	29.53	54.78	12.64	1.15	5,850	5,670	4,931	739
155	No. 6	Pratt	Dolomite	50	do	....	....	....	....	2.44	25.96	64.70	6.90	.59	12,000	11,707	10,879	828
	Argentina:																	
141	Argentina (special)	....	....	0	Slack	....	....	....	....	7.67	18.39	31.09	42.85	1.21	....	....	....	....
169	Jamestown No. 8	....	....	0	do	....	....	....	....	8.67	18.03	29.98	43.32	.56	....	....	....	....
	Arkansas:																	
96	No. 7A	Hartshorne	Midland	50	Lump	47	15	10	28	4.27	16.04	67.43	12.26	2.15	12,900	12,350	10,767	1,583
95	No. 8	(?)	Spadra	26	Over 4 inches	13	6	13	68	2.74	9.70	71.95	15.61	2.45	8,550	8,320	6,986	1,334
91	No. 10	(?)	Lester	18	Run of mine	....	....	....	....	39.43	26.49	24.37	9.71	.49	8,250	4,999	4,198	801
44	Brazil: No. 1	....	Rio Grande do Sul	24	do	....	....	....	....	10.96	26.78	38.82	23.44	2.94	8,100	7,215	5,316	1,899
	California:																	
32	No. 1	Eureka and Summit.	Tesla	42	do	....	....	....	....	17.36	38.41	28.76	15.47	2.96	23,850	19,720	16,030	3,690
33	No. 1[a]	do	do	0	do	....	....	....	....	10.46	21.21	52.90	15.43	1.87	....	....	....	....
34	No. 1[a]	do	do	24	do	....	....	....	....	12.77	26.16	45.56	15.51	2.28	11,850	10,308	8,469	1,839
15	Colorado: No. 1	....	Lafayette	30	do	....	....	....	....	20.24	32 26	41.65	5.85	.60	10,933	8,720	8,080	640
117	Florida: No. 1	Peat	Orlando	50	Briquet	....	....	....	....	21.00	51.72	22.11	5.17	.45	29,250	23,100	21,587	1,513
	Illinois:																	
6	No. 3	No. 7	Marion	30	Run of mine	....	....	....	....	7.62	30.87	51.78	9.73	1.69	10,500	9,700	8,679	1,021
9	No. 4	No. 6	Troy	30	Over 2 inches	....	....	....	....	12.43	32.65	45.70	9.22	1.41	10,500	9,190	8,222	968
35	No. 6B	do	Coffeen	60	Lump	....	....	....	....	11.47	31.67	40.78	16.08	4.59	23,400	20,700	16,940	3,760
26	No. 7A	do	Collinsville	11⅓	Slack	....	....	....	....	12.76	32.35	33.37	21.52	3.82	[b] 7,350	....	....	....
27	No. 7B	do	do	30	Over 1 inch	....	....	....	....	11.92	33.95	36.67	17.46	4.15	13,650	12,030	9,647	2,383
38	No. 7C	do	do	33	Slack	....	....	....	....	10.08	32.71	38.26	18.95	4.15	15,750	14,160	11,173	2,987
29	No. 8	do	Paisley	42	Nut	....	....	....	....	12.91	33.83	41.67	11.59	4.64	16,050	13,990	12,129	1,861
28	No. 9B	do	Staunton	60	Lump	....	....	....	....	11.99	35.90	40.63	11.48	4.92	23,700	20,860	18,138	2,722

31	No. 10	No. 7	West Frankfort	50	Slack	....	....	....	....	8.57	32.31	48.45	10.67	1.35	15,600	14,260	12,595	1,665
30	No. 11A	do	Carterville	53	Egg	....	....	....	....	7.08	32.62	49.44	10.86	2.09	15,450	14,350	12,672	1,678
36	No. 11C c	do	do	24	Slack	....	....	....	....	12.78	28.03	47.63	11.56	1.65	b13,650	......	......	......
42	No. 11D c	do	do	50	Nut	....	....	....	....	8.67	30.69	53.36	7.28	1.53	12,600	11,500	10,582	918
48	No. 11D c	do	do	50	do	9	16	62	13	7.99	32.08	52.76	7.17	1.56	12,450	11,450	10,558	892
41	No. 13	do	Benton	50	Egg	....	....	....	....	8.72	31.07	49.94	10.27	1.66	16,950	15,475	13,733	1,742
37	No. 14	No. 5	Springfield	50	Over 1½ inches	....	....	....	....	12.68	33.36	41.57	12.39	4.16	16,650	14,540	12,478	2,062
39	No. 15	No. 6	Centralia	0	Over 6 inches	....	....	....	....	......	......	......	......	......	......	......	......	......
40	No. 15	do	do	50	do	....	....	....	....	9.44	35.48	41.53	13.55	4.06	16,950	15,360	13,061	2,299
43	No. 16	No. 7	Herrin	50	Over 3 inches	....	....	....	....	7.68	30.62	51.33	10.37	1.47	17,250	15,920	14,132	1,788
45	No. 18	No. 2	La Salle	50	Over 6 inches	....	....	....	....	13.19	35.93	40.84	10.04	4.59	16,200	14,060	12,434	1,626
55	No. 19B	No. 7	Zeigler	50	Over ¾ inch	9	5	9	77	9.64	30.68	50.22	9.46	.53	13,950	12,610	11,290	1,320
128	No. 19C	do	do	50	Run of mine	....	....	....	....	9.82	29.64	50.34	10.20	.49	14,400	12,990	11,520	1,470
105	No. 21	No. 6	Troy	562	Lump	....	....	....	....	14.68	30.98	42.93	11.41	1.33	208,350	177,764	153,997	23,767
102	No. 22A	do	Maryville	47	do	....	....	....	....	11.29	35.60	39.94	13.17	4.88	16,300	14,460	12,315	2,145
98	No. 23A	do	Donkville	50	Over 5 inches	12	4	3	81	11.87	36.37	39.87	11.89	4.65	18,000	15,860	13,720	2,140
100	No. 23B c	do	do	50	Slack	22	20	24	34	14.77	35.23	40.98	9.02	3.46	17,250	14,700	13,145	1,555
103	No. 24B	do	New Baden	50	Lump	11	10	16	63	11.44	33.93	43.92	10.71	4.94	14,650	12,970	11,401	1,569
104	No. 25	do	Germantown	50	do	....	....	....	....	11.35	34.62	40.63	13.40	4.76	16,000	14,180	12,037	2,143
126	No. 26	No. 5	Lincoln	50	Run of mine	....	....	....	....	13.29	32.02	38.81	15.88	3.52	16,050	13,910	11,362	2,548
127	No. 27	No. 6	Auburn	50	do	....	....	....	....	11.35	33.59	41.20	13.86	4.54	16,050	14,230	12,006	2,224
139	No. 29B	No. 5	Livingston	50	do	10	7	17	66	12.25	33.76	41.66	12.33	4.42	17,250	15,140	13,012	2,128
157	No. 30 c	No. 7	Shiloh	50	Nut	....	....	....	....	5.59	39.30	45.45	9.66	3.37	16,200	15,300	13,734	1,566
	Indiana:																	
14	No. 1	No. 6	Mildred	29⅔	Run of mine	....	....	....	....	11.51	36.04	42.37	10.08	2.61	11,700	11,360	9,180	1,180
13A	No. 2	No. 5	Boonville	21	do	....	....	....	....	8.72	39.60	41.95	9.73	4.23	6,900	6,300	5,628	672
13B	No. 2	do	do	7	do	....	....	....	....	8.72	39.60	41.95	9.73	4.23	2,100	1,917	1,713	204
53	No. 3 c	do	do	50	Nut and slack	....	....	....	....	11.85	36.85	43.15	8.15	3.64	17,550	15,460	14,030	1,430
46	No. 5	do	Hymera	30	Run of mine	....	....	....	....	10.02	35.49	41.98	12.51	6.04	11,850	10,660	9,176	1,484
47	No. 5	do	do	50	do	....	....	....	....	10.49	35.90	43.25	10.36	4.14	14,250	12,750	11,274	1,476
49	No. 6	No. 4	do	50	do	....	....	....	....	10.89	36.19	40.43	12.49	4.71	17,850	15,900	13,670	2,230
51	No. 7A	No. 5	Littles	45	Over 1⅜ inches	11	7	13	69	7.73	39.19	42.47	10.61	5.20	13,650	12,600	11,150	1,450
57	No. 8	No. 7	Terre Haute	50	Lump	8	5	9	78	9.21	36.78	42.66	11.35	3.80	15,300	13,890	12,154	1,736
52	No. 9A	do	Macksville	45	do	7	5	10	78	12.52	36.13	41.25	10.10	2.76	15,450	13,510	11,950	1,560
61	No. 11	No. 4	Dugger	40	do	....	....	....	....	13.03	32.52	46.19	8.26	1.68	12,750	11,090	10,036	1,054
99	No. 12	No. 5	Hartwell	50	Run of mine	18	12	23	47	10.42	36.29	40.75	12.54	3.96	17,200	15,400	13,242	2,158
132	No. 13	No. 6	Terre Haute	50	do	24	16	24	36	11.53	34.80	40.44	13.23	3.11	15,300	13,540	11,515	2,025
138	No. 13	do	do	24	do	8	12	26	54	10.70	35.58	42.85	10.87	3.06	6,750	6,030	5,296	734
131	No. 14	No. 3	Seelyville	50	do	12	12	26	50	7.88	36.85	41.07	14.20	5.14	16,200	14,920	12,620	2,300
134	No. 15	No. 4	Linton	50	do	16	12	19	53	11.42	34.11	45.82	8.65	1.03	14,650	12,980	11,711	1,269
137	No. 15	do	do	50	do	21	11	20	48	11.42	34.11	45.82	8.65	1.03	14,050	12,450	11,234	1,216
130	No. 16	No. 5	do	50	do	....	....	....	....	7.79	35.32	44.97	11.92	4.01	16,100	14,850	12,930	1,920
133	No. 18B	do	Ayrshire	36	Lump	12	9	17	62	11.13	35.11	46.78	6.98	1.64	10,350	9,200	8,478	722
135	No. 18B	do	do	50	do	12	8	15	65	12.11	34.19	46.87	6.83	1.44	16,350	14,370	13,253	1,117
	Indian Territory:																	
1	No. 1	(?)	Henryetta	31	Lump and slack	....	....	....	....	5.00	36.51	49.98	8.51	1.43	11,200	10,640	9,685	955
20	No. 4	McAlester	Lehigh	22⅔	Lump	....	....	....	....	9.00	33.96	40.68	16.36	4.12	6,300	5,740	4,707	1,033

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[a] Mixed with 50 per cent "front-end" cinders from locomotives in test 33, and with 33⅓ per cent of the same cinders in test 34.

[b] Fuel actually charged in producer. No data available for making correction for change in thickness of bed.

[c] Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Origin of fuel sample.		Duration of test (hours).	Size of fuel.					Proximate analysis of fuel as fired (per cent).					Total fuel charged in producer (pounds).			
		Name of bed.	Location of mine or deposit.		As shipped.	As used (per cent).				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur (separately determined).	As fired.	Dry.	Combustible.	Refuse (determined from analysis).
						Under ¼ inch.	¼ to ½ inch.	½ to 1 inch.	Over 1 inch.									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	20	18
22	Iowa: No. 2	Big Vein	Liberty Twp., Marion County.	13⅓	Run of mine	....	....	....	....	16.69	31.42	31.19	20.70	5.50	4,833	4,030	3,030	1,000
	Kansas:																	
24	No. 5	Weir-Pittsburg	West Mineral	13	Over ⅝ inch	....	....	....	....	4.35	31.97	52.43	11.25	3.00	4,000	3,826	3,375	450
25	No. 5	do	do	30	do	....	....	....	....	4.23	31.49	54.09	10.19	3.18	8,650	8,280	7,400	880
101	No. 6	do	Jewett	13⅔	Lump	10	9	17	64	9.85	30.19	46.68	13.28	3.04	4,500	4,058	3,460	598
	Kentucky:																	
79	No. 1B	Straight Creek	Straight Creek	50	Egg	0	1	5	94	2.61	36.29	57.73	3.37	.88	13,050	12,710	12,270	440
12	No. 3	No. 9	Barnsley	30	Run of mine	....	....	....	....	7.28	38.57	45.16	8.99	3.86	11,100	10,300	9,300	1,000
81	No. 5	High Splint	Big Black Mountain.	50	do	11	8	10	71	3.75	36.05	56.17	4.03	.47	12,900	12,410	11,890	520
85	No. 6	No. 1	Paintsville	50	do	11	5	11	73	4.49	36.82	55.28	3.41	.51	12,600	12,030	11,600	430
84	No. 7	No. 9	Central City	50	Over 1½ inches.	7	6	14	73	8.47	35.24	46.81	9.48	3.60	15,300	14,000	12,550	1,450
97	Massachusetts: No. 1	Peat	Halifax	9	Briquet	12	4	3	81	49.80	27.27	10.88	12.05	.34	6,480	3,254	2,473	781
	Missouri:																	
7A	No. 2	Bevier	Bevier	6⅓	Run of mine	....	....	....	....	11.60	35.28	38.28	14.84	4.56	3,300	2,920	2,430	490
7B	No. 2	do	do	4⅓	do	....	....	....	....	11.60	35.28	38.28	14.84	4.56	1,500	1,326	1,103	223
	Montana:																	
5A	No. 1	(?)	Red Lodge	22⅓	Washed nut	....	....	....	....	11.40	34.55	43.31	10.74	1.72	10,200	9,037	7,942	1,095
5B	No. 1	(?)	do	4⅔	do	....	....	....	....	11.40	34.55	43.31	10.74	1.72	1,800	1,595	1,402	193
149	No. 2	(?)	Fromberg	40	Run of mine	18	10	21	51	8.51	31.58	44.52	15.39	.60	15,450	14,140	11,760	2,380
150	No. 3	(?)	Bridger	49	do	....	....	....	....	8.56	32.36	45.69	13.39	.54	15,950	14,590	12,452	2,138
	New Mexico:																	
121	No. 3A	Main Ratou or Lower Laramie.	Van Houten	50	do	....	....	....	....	3.62	31.56	45.19	19.63	.72	12,850	12,390	9,868	2,522
122	No. 4A	do	do	50	do	....	....	....	....	2.42	34.82	49.23	13.53	.63	13,110	12,790	11,016	1,774
120	No. 5	do	do	45	do	....	....	....	....	1.79	31.32	51.40	15.49	.66	12,500	12,270	10,335	1,935
	North Dakota:																	
68	No. 1B	Lignite	Lehigh	49	do	7	5	9	79	32.64	29.19	26.75	11.42	3.54	26,000	17,510	14,540	2,970

10	No. 2	do	Williston	30	(?)	....	....	....	....	39.56	27.78	26.30	6.36	.93	13,800	8,340	7,462	878
72	No. 2B	do	do	50	Run of mine	6	5	7	82	36.13	29.28	29.55	5.04	.59	26,000	16,610	15,297	1,313
152	No. 2B	do	do	12	do	....	....	....	....	38.92	25.54	30.15	5.39	.48	6,400	3,910	3,565	345
67	No. 3	do	Wilton	50	Lump	6	3	6	85	35.78	28.76	29.01	6.45	.90	30,250	19,420	17,470	1,950
	Ohio:																	
64	No. 3 [a]	No. 6	Shawnee	50	Run of mine	6	9	38	47	8.13	34.64	49.45	7.78	1.40	14,250	13,095	11,986	1,109
60	No. 4	No. 8	Bradley	25	Lump	....	....	....	....	5.03	36.68	50.70	7.59	2.77	6,300	5,980	5,502	478
58	No. 5	do	Rush Run	50	Nut	5	3	7	85	4.39	35.91	53.77	5.93	1.42	11,850	11,340	10,637	703
76	No. 6	do	Neffe	50	Run of mine	15	10	14	61	3.61	38.05	49.68	8.66	3.76	11,850	11,420	10,394	1,026
87	No. 7	No. 7	Danford	41	Lump	10	6	12	72	5.29	35.86	50.73	8.12	2.34	12,850	12,160	11,119	1,041
83	No. 8	No. 6	Dixie	50	Run of mine	19	9	14	58	8.70	35.58	43.63	12.09	3.82	14,850	13,560	11,765	1,795
73	No. 9A	No. 4	Clarion	50	Lump	13	11	14	62	7.22	38.32	46.23	8.23	3.52	12,800	11,880	10,826	1,054
142	No. 10	No. 5	Mineral City	50	do	11	8	17	64	4.05	39.28	47.75	8.92	3.02	12,650	12,140	11,011	1,129
145	No. 11	No. 8	Flushing	50	do	13	7	14	66	3.44	36.04	47.58	12.94	4.32	13,850	13,370	11,578	1,792
146	No. 12	do	Bellaire	34	Run of mine	7	10	21	62	2.97	37.61	49.45	9.97	3.65	10,650	10,340	9,277	1,063
147	No. 12	do	do	50	do	19	11	18	52	3.82	37.77	47.42	10.99	3.39	14,350	13,800	12,222	1,578
	Pennsylvania:																	
65	No. 4	Pittsburg	Greensburg	50	Lump	10	6	9	75	1.79	30.17	57.04	11.00	1.35	13,200	12,960	11,507	1,453
59	No. 5B	do	Ellsworth	50	Nut	....	....	....	....	3.42	32.73	56.13	7.72	.81	12,150	11,740	10,801	939
66	No. 6 [a]	do	East Millsboro	47	Run of mine	20	15	20	45	2.15	35.01	55.18	7.66	1.60	13,000	12,720	11,724	996
70	Nos. 6A and 6B	do	do	50	do	12	7	16	65	2.86	31.88	53.35	11.91	2.04	11,250	10,930	9,590	1,340
88	No. 7	do	Ligonier	50	do	28	15	16	41	3.52	22.25	61.57	12.66	1.99	13,350	12,890	11,200	1,690
63	No. 8	Lower Kittanning	Ehrenfeld	50	do	....	....	....	....	2.49	16.61	73.70	7.20	.91	11,100	10,830	10,031	799
71	No. 10	Pittsburg	Bruce	50	Over ¾ inch	....	....	....	....	2.77	33.94	54.84	8.45	1.37	12,300	11,950	10,911	1,039
129	No. 11	do	Charleroi	50	Run of mine	....	....	....	....	1.95	34.07	56.69	7.29	1.18	12,200	11,970	11,081	889
143	No. 12	do	Acheson	28	do	45	18	17	20	1.96	30.55	58.24	9.25	2.19	6,100	5,980	5,416	564
136	No. 13	Freeport	Creighton	50	do	12	8	15	65	2.65	33.02	51.17	13.16	2.16	12,600	12,270	10,611	1,659
140	No. 13	do	do	50	do	15	12	24	49	1.65	33.06	53.22	12.07	1.80	11,750	11,550	10,132	1,418
144	No. 15	B. or Miller	Wehrum	24	do	61	18	14	7	2.57	18.09	69.01	10.33	3.97	5,700	5,555	4,966	589
148	No. 16	D	Hastings	50	do	....	....	....	....	5.32	21.75	64.94	7.99	1.60	[b] 9,950	9,425	8,629	796
158	No. 17	Upper Freeport	White	50	do	....	....	....	....	4.40	28.01	54.87	12.72	1.75	13,200	12,620	10,940	1,680
159	No. 22	Pittsburg	Huff	50	do	....	....	....	....	3.98	28.13	57.73	10.16	1.00	11,700	11,230	10,042	1,188
113	Rhode Island: No. 1	(?)	Cranston	0	do	....	....	....	....	2.41	4.92	73.61	19.06	.07	......	......	......	......
	Tennessee:																	
115	No. 1	Mingo	Fork Ridge	50	do	....	....	....	....	2.72	31.81	53.20	12.27	1.26	12,300	11,970	10,460	1,510
107	No. 2	Leg Mountain	Gatliff	50	do	....	....	....	....	3.40	37.58	54.27	4.75	.83	11,250	10,870	10,335	535
106	No. 3	Regal Block	do	50	do	....	....	....	....	4.88	34.84	53.57	6.71	1.16	12,950	12,320	11,452	868
111	No. 4	Windrock or Dean	Oliver Springs	50	do	....	....	....	....	3.29	34.49	54.82	7.40	.88	12,150	11,750	10,850	900
125	No. 5	Brushy Mountain	Petros	50	do	....	....	....	....	2.54	34.64	53.96	8.86	3.39	12,900	12,580	11,436	1,144
110	No. 6	Lower Sewanee	Waldensia	30	do	....	....	....	....	3.55	26.00	49.88	20.57	.76	7,950	7,670	6,034	1,636
108	No. 7A	Wilder	Wilder	50	do	....	....	....	....	3.03	34.91	49.21	12.85	3.26	14,400	13,970	12,119	1,851
116	Nos. 8A and 8B [a]	First above Sewanee.	Clifty	50	do	....	....	....	....	1.62	34.44	53.32	10.62	3.05	11,250	11,070	9,876	1,194
119	Nos. 8A and 8B [a]	do	do	24	do	....	....	....	....	2.43	35.41	52.29	9.87	3.06	6,550	6,390	5,744	646
	Texas:																	
11	No. 1	(?)	Wootter's Station	21⅔	Over ½ inch	....	....	....	....	33.50	32.34	23.80	10.36	.63	12,800	8,510	7,183	1,327
18	No. 2	(?)	Hoyt	19⅓	Lump	....	....	....	....	33.71	29.25	29.76	7.28	.53	9,050	5,999	5,340	659
93	No. 3	(?)	Olsen	50	do	13	8	18	61	32.20	30.11	28.82	8.87	.88	25,500	17,290	15,029	2,261
92	No. 4	(?)	Hoyte	50	Run of mine	9	7	16	68	34.08	33.15	25.32	7.45	.49	24,550	16,180	14,351	1,829
118	Utah: No. 1	(?)	Huntington Creek	50	do	....	....	....	....	5.83	42.46	47.05	4.66	.57	14,250	13,420	12,755	665

[a] Washed.

[b] No measurements of ash bed. Rise in bed figured from analysis of coal.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Origin of fuel sample.		Duration of test (hours).	Size of fuel.					Proximate analysis of fuel as fired (per cent).					Total fuel charged in producer (pounds)			
		Name of bed.	Location of mine or deposit.		As shipped.	As used (per cent).				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur (separately determined).	As fired.	Dry.	Combustible.	Refuse (determined from analysis).
						Under ¼ inch.	¼ to ½ inch.	½ to 1 inch.	Over 1 inch.									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	20	18
	Virginia:																	
77	No. 1	Wilson	Crab Orchard	50	Run of mine	....	....	....	....	5.72	31.93	55.91	6.44	1.08	14,100	13.290	12,382	908
78	No. 2	McConnell	do	50	do	9	6	11	74	2.36	36.40	55.44	5.80	.67	12,950	12.640	11,889	751
75	No. 3	Upper Banner	Toms Creek	50	Lump	22	13	14	51	1.66	31.68	61.76	4.90	.49	11,050	10.860	10,319	541
74	No. 4	Darby	Darby	50	do	....	....	....	....	2.72	36.79	57.72	2.77	.42	12,200	11,870	11.532	338
154	No. 5A	Big Seaur	Blocksburg	30	Pea	....	....	....	....	3.34	11.28	67.24	18.14	.75	7,950	7.690	6,246	1,444
160	No. 6	No. 4	Richlands	50	Run of mine	....	....	....	....	4.51	22.77	62.64	10.08	1.59	11,000	10.510	9,400	1,110
163	Jamestown No. 1	Jaw Bone	Virginia City	8	do	....	....	....	....	1.29	29.70	53.65	15.36	1.14	1,950	1,925	1,625	300
	Washington:																	
90	No. 1A [a]	(?)	Renton	40	Pea	25	31	35	9	16.17	34.00	37.27	12.56	.53	[b]18,900	15.850	13,475	2,375
89	No. 1B	(?)	do	40	Run of mine	30	15	10	45	16.21	34.07	36.35	13.37	.58	16,450	13.790	11,590	2,200
94	No. 1B	(?)	do	14	do	13	9	10	68	16.02	33.27	36.81	13.90	.59	6,550	5,500	4,590	910
112	No. 2	(?)	Roslyn	35	Lump	....	....	....	....	4.01	34.61	47.49	13.89	.38	9,300	8,930	7,638	1,292
	West Virginia:																	
3	No. 1	Pittsburg	Kingmont	24	Run of mine	....	....	....	....	1.61	36.85	55.40	6.14	.87	6,900	6,790	6,367	423
4	No. 4	Upper Freeport	Bretz	9	do	....	....	....	....	1.99	28.89	60.30	8.82	.79	2,100	2,058	1,873	185
23	No. 7	Sewell	Sun	22⅔	do	....	....	....	....	2.99	21.19	69.15	6.67	.92	6,000	5,820	5,420	400
19	No. 8	Ansted	Ansted	21	do	....	....	....	....	2.66	32.58	59.00	5.76	.94	6,900	6,720	6,322	398
17A	No. 9	Powellton	Powellton	5⅓	do	....	....	....	....	2.66	32.00	59.61	5.73	1.00	1,300	1,265	1,191	74
17B	No. 9	do	do	6⅓	do	....	....	....	....	2.66	32.00	59.61	5.73	1.00	1,900	1,848	1,739	109
21	No. 9	do	do	21	do	....	....	....	....	2.22	31.05	59.83	6.90	.79	6,000	5,867	5,453	414
161	No. 11B	Pocahontas No. 3	Zenith	50	Lump	....	....	....	....	.47	8.83	46.96	43.74	.27	18,909	18,810	10,540	8,270
8	No. 12	Tug River	Big Sandy	30	Run of mine	....	....	....	....	1.43	18.93	73.19	6.45	.95	8,100	7,984	7,462	522
56	No. 13	Ansted	Page	50	do	13	20	42	25	2.65	31.00	62.82	3.53	.82	[b]9,750	9,490	9,145	345
54	No. 14	Eagle	do	47	do	48	19	14	19	3.12	28.99	65.22	2.67	1.21	[b]9,750	9,450	9,189	261
86	No. 16A	Pittsburg	Monongahela	50	Nut	5	4	5	86	2.28	35.54	55.29	6.89	.95	13,150	12,850	11,944	906
80	No. 18	Glen Alum	Glen Alum	50	Run of mine	11	7	13	69	2.66	32.71	58.89	5.74	.65	11,250	10,940	10,294	646
82	No. 20	Keystone	Acme	50	do	....	....	....	....	1.83	32.94	57.63	7.60	1.71	12,150	11,930	11.006	924

162	No. 24	Pocahontas No. 3.	Gary	50	Slack					2.91	11.81	57.19	28.08	.54	11,000	10,680	7,590	3,090
156	No. 25	Black Band	Charleston	50	Lump					3.83	34.34	53.61	8.22	.62	13,000	12,500	11,432	1,068
164	Jamestown No. 3	Pocahontas	Davy	144	Run of mine					1.36	14.72	76.42	7.50	.91	31,718	31,288	28,910	2,378
165	Jamestown No. 4	Quinnemont (Fire Creek).	Rush Run	240	do					1.62	18.86	74.11	5.41	.69	51,439	50,606	47,823	2,783
166	Jamestown No. 5	Sewell	Sewell	213⅓	do					1.94	21.42	70.17	6.47	.65	44,853	43,983	41,080	2,903
167	Jamestown No. 7	do	Derryhale	44	do					1.68	18.01	74.85	5.46	.83	10,309	10,136	9,574	562
168	Jamestown No. 7	do	do	240	do					1.68	18.01	74.85	5.46	.83	52,252	51,374	48,523	2,851
	Wyoming:																	
16	No. 2	(?)	Cambria	30	Over ¼ inch					9.44	35.02	34.82	20.72	3.91	12,100	10,958	8,449	2,509
62	No. 2B	(?)	do	49	Run of mine	10	13	18	59	8.63	36.81	32.83	21.73	4.47	20,400	18,650	14,215	4,435
69	No. 3	(?)	Aladdin	47	do	14	12	15	59	13.02	37.56	34.05	15.37	7.36	17,400	15,140	12,464	2,676
123	No. 4	(?)	Hanna	50	do					11.30	40.32	41.07	7.31	.28	20,200	17.920	16,443	1,477
114	No. 5	Rock Springs	Rock Springs	50	do					11.44	36.37	48.49	3.70	.91	15,600	13,810	13,232	578
124	No. 6	(?)	Kemmerer	50	do					18.26	37.18	41.82	2.74	.47	21,900	17,900	17,300	600
	Miscellaneous:																	
151.	Coke			41						7.86	.69	79.94	11.51	1.14	[b]8,400			
50	Coke breeze			30						13.45	2.57	69.57	14.41	.73	11.800	10,210	8,510	1.700
153	Refuse			0						11.29	19.07	29.51	40.13	3.54				

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[a] Washed.

[b] Fuel actually charged in producer. No data available for making correction for change in thickness of bed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Fuel charged per hour (pounds).									Calorific value (British thermal units).[a]							
		In producer.			In producer plant.			Per square foot of fuel-bed area.			Fuel.				Standard gas (at 62° F. and 14.7 pound pressure).			
											Per pound.			Per hour as fired.	Per pound of fuel.		Per cubic foot.	Per brake-horsepower hour.
		As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.		As fired.	Dry.		
1	2	21	22	23	24	25	26	27	28	29	37	38	39	40	41	42	43	45
	Alabama:																	
2	No. 2	310.5	299.0	269.5	341.4	328.7	296.3	8.07	7.78	7.01	12,865	133365	14,820	3,995,000	8,340	8,670	143.5	10,645
109	No. 4	243.9	236.2	205.7	265.2	256.9	223.7	6.34	6.14	5.34	12,953	13,360	15,360	3,159,000	11,450	11,830	152.0	12,170
155	No. 6	240.0	234.1	217.6	256.6	250.3	232.7	6.23	6.08	5.66	14,170	14,524	15,630	3,400,000	10,130	10,385	143.7	10,400
	Argentina:																	
141	Argentina (special	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
169	Jamestown No. 8	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
	Arkansas:																	
96	No. 7A	258.0	247.0	215.3	280.5	268.6	234.8	6.70	6.42	5.60	12,773	13,340	15,300	3,294,000	9,205	9,619	125.5	14,700
95	No. 8	328.9	320.0	268.5	358.1	348.4	292.3	8.54	8.31	6.97	12,546	12,901	15,370	4,128,000	8,050	8,275	130.0	12,700
91	No. 10	458.5	277.6	233.0	523.4	316.9	266.0	11.91	7.21	6.05	6,356	10,492	12,500	2,912,000	3,295	5,440	125.3	9,970
44	Brazil No. 1	337.5	300.5	221.4	369.2	328.7	242.2	8.78	7.82	5.76	9,058	10,175	13,810	3,059,000	6,305	7,080	130.9	12,750
	California:																	
32	No. 1	568.0	469.4	381.5	597.3	493.6	401.2	14.78	12.22	9.93	8,530	10,321	12,700	4,842,000	5,070	6,140	158.3	11,810
33	No. 1[a]	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
34	No. 1[b]	494.0	429.5	353.0	......	......	......	12.85	11.18	9.18	9,474	10,831	13,186	4,680,000	5,245	6,044	132.6	10,690
15	Colorado: No. 1	364.4	290.7	269.3	428.4	341.7	316.6	9.48	7.56	7.00	9,767	12,245	13,210	3,560,000	6,270	7,860	149.0	9,700
117	Florida: No. 1	585.0	462.0	431.7	620.6	490.1	458.0	15.20	12.00	11.20	8,127	10,289	11,100	4,756,000	5,300	6,710	175.2	12,840
	Illinois:																	
6	No. 3	350.0	323.3	289.3	386.0	356.7	319.2	9.10	8.41	7.53	12,046	13,041	14,560	4,215,000	7,710	8,330	154.8	11,460
9	No. 4	350.0	306.3	274.1	398.2	348.5	311.9	9.10	7.96	7.12	11,237	12,834	14,344	3,930,000	7,770	8,880	152.1	11,660
35	No. 6B	390.0	345.0	282.3	418.2	369.9	302.6	10.15	8.98	7.34	10,141	11,453	14,000	3,955,000	7,040	7,965	152.0	11,300
26	No. 7A	......	......	......	......	......	......	......	......	......	9,300	10,721	14,260	......	......	......	109.3	11,610
27	No. 7B	455.0	401.0	321.6	492.1	433.7	347.8	11.84	10.44	8.36	9,970	11,308	14,100	4,535,000	5,970	6,770	138.6	11,300
28	No. 7C	477.3	429.0	338.5	508.5	457.0	360.6	12.42	11.16	8.80	9,958	11,072	14,040	4,750,000	4,980	5,540	120.2	11,550
29	No. 8	382.2	333.0	288.9	411.5	358.5	311.0	9.94	8.66	7.52	10,680	12,263	14,140	4,083,000	7,160	8,220	147.0	11,170

28	No. 9B	395.0	347.7	302.3	418.1	368.0	320.0	10.30	9.00	7.90	10,854	12,334	14,180	4,287,000	6,900	7,840	143.7	11,140
31	No. 10	312.0	285.2	251.9	329.5	301.2	266.0	8.12	7.42	6.55	11,768	12,874	14,580	3,674,000	8,735	9,559	139.1	11,156
30	No. 11A	291.5	271.0	239.0	305.8	284.3	250.7	7.58	7.05	6.22	12,004	12,919	14,640	3,500,000	10,060	10,810	166.3	11,870
36	No. 11C c	......	......	......	......	......	......	......	......	......	10,865	12,456	14,380	......	......	......	109.8	11,455
42	No. 11D c	252.0	230.0	211.7	277.1	252.9	232.7	6.55	5.98	5.50	12,361	13,534	14,710	3,115,000	10,330	11,320	137.6	11,010
48	No. 11D c	249.0	229.0	211.2	277.7	255.4	235.5	6.48	5.96	5.50	12,474	13,554	14,700	3,106,000	......	......	154.9	......
41	No. 13	339.0	309.5	274.7	362.6	331.0	293.8	8.82	8.05	7.14	11,686	12,798	14,420	3,963,000	7,479	8,180	138.3	10,319
37	No. 14	333.0	290.8	249.6	356.0	310.9	266.8	8.66	7.56	6.49	10,679	12,231	14,250	3,560,000	7,760	8,900	150.6	11,040
39	No. 15	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
40	No. 15	339.0	307.2	261.3	360.2	326.4	373.4	8.82	7.99	6.80	10,964	12,107	14,240	3,720,000	8,060	8,900	142.9	11,570
43	No. 16	345.0	318.4	282.6	364.1	336.1	298.3	8.97	8.28	7.35	11,920	12,911	14,540	4,111,000	7,820	8,480	149.5	11,400
45	No. 18	324.0	281.2	248.7	350.3	304.0	268.9	8.43	7.32	6.47	11,039	12,717	14,380	3,576,000	8,120	9,360	147.7	11,080
55	No. 19B	279.0	252.2	225.8	294.8	266.5	238.6	7.26	6.56	5.87	11,871	13,140	14,680	3,316,000	10,260	11,340	164.1	12,090
128	No. 19C	288.0	259.8	230.4	314.4	283.6	251.5	7.48	6.75	5.99	11,493	12,744	14,360	3,310,000	8,180	9,080	137.8	14,200
105	No. 21	370.7	316.3	274.0	396.4	338.2	293.0	9.63	8.22	7.12	10,528	12,343	14,250	3,905,000	7,650	8,970	156.1	12,580
102	No. 22A	347.0	307.8	262.0	368.3	326.7	278.1	9.02	8.00	6.81	10,735	12,100	14,220	3,726,000	7,940	8,950	159.6	11,900
98	No. 23A	360.0	317.2	274.4	379.1	334.1	289.0	9.35	8.24	7.13	10,667	12,103	14,000	3,840,000	7,290	8,280	147.9	11,260
100	No. 23B c	345.0	294.0	262.9	374.9	319.5	285.7	8.96	7.64	6.82	10,804	12,676	14,170	3,727,000	7,370	8,640	145.0	11,900
103	No. 24B	293.0	259.4	228.0	311.8	276.1	242.7	7.62	6.74	5.93	10,958	12,375	14,080	3,210,000	8,620	9,730	160.5	10,700
104	No. 25	320.0	283.6	240.7	337.7	299.3	254.0	8.32	7.37	6.25	10,733	12,105	14,260	3,433,000	7,640	8,620	168.0	11,350
126	No. 26	321.0	278.2	227.2	348.4	301.9	246.6	8.34	7.23	5.90	10,013	11,547	14,140	3,214,000	8,050	9,290	147.2	12,580
127	No. 27	321.0	284.6	240.0	347.4	308.0	259.8	8.34	7.39	6.23	10,485	11,828	14,030	3,368,000	6,450	7,280	122.5	14,090
139	No. 29B	345.0	302.8	260.2	370.3	325.0	279.2	8.96	7.86	6.76	10,719	12,250	14,220	3,700,000	......	......	141.2	......
157	No. 30 c	324.0	306.0	274.7	339.5	320.7	287.9	8.42	7.95	7.13	12,188	12,910	14,380	3,950,000	7,530	7,980	154.4	10,430
	Indiana:																	
14	No. 1	394.5	349.3	309.5	434.6	384.8	341.0	10.30	9.10	8.05	11,534	13,037	14,720	4,553,000	6,840	7,730	153.7	11,480
13A	No. 2	328.5	300.0	268.0	370.1	338.0	302.0	8.55	7.80	6 97	11,822	12,953	14,500	3,883,000	6,740	7,380	139.6	11,300
13B	No. 2	300.0	274.0	244.8	338.0	312.0	278.8	7.80	7.10	6.40	11,822	12,953	14,500	3,550,000	9,275	10,140	159.3	11,750
53	No. 3 c	351.0	309.2	280.6	372.5	328.2	297.8	9.13	8.05	7.30	11,417	12,953	14,280	4,010,000	7,130	8,100	137.2	11,220
46	No. 5	395.0	355.3	305.9	427.5	384.5	331.0	10.27	9.25	7.96	11,052	12,285	14,270	4,369,000	6,250	6,950	136.7	10,540
47	No. 5	285.0	255.0	225.5	304.4	272.3	240.8	7.42	6.64	5.86	11,520	12,870	14,560	3,283,000	8,640	9,650	145.0	10,340
49	No. 6	357.0	318.0	273.4	387.3	345.0	296.6	9.29	8.28	7.11	11,158	12,519	14,570	3,983,000	......	......	150.9	......
51	No. 7A	303.5	280.0	247.8	326.5	301.2	266.6	7.90	7.28	6.44	11,810	12,798	14,460	3,585,000	8,380	9,075	158.5	10,890
57	No. 8	306.0	277.8	243.1	322.7	292.9	256.3	7.96	7.22	6.32	11,687	12,870	14,720	3,578,000	8,640	9,520	151.5	11,220
52	No. 9A	343.3	300.2	265.6	360.7	315.4	279.0	8.93	7.81	6.91	11,246	12,857	14,540	3,862,000	7,980	9,120	151.8	11,880
61	No. 11	318.8	277.3	250.9	346.8	301.6	272.9	8.29	7.22	6.52	11,581	13,316	14,730	3,697,000	8,050	9,260	147.1	10,900
99	No. 12	344.0	308.0	264.8	364.4	326.3	280.5	8.94	8.00	6.88	11,146	12,442	14,470	3,832,000	7,780	8,685	149.4	11,700
132	No. 13	306.0	270.8	230.3	333.5	295.2	250.8	7.95	7.03	5.99	10,924	12,348	14,520	3,341,000	7,330	8,290	131.9	11,930
138	No. 13	281.2	251.2	220.6	304.9	272.4	239.2	7.30	6.52	5.73	11,408	12,775	14,550	3,210,000	......	......	148.0	......
131	No. 14	324.0	298.4	252.4	343.4	316.2	267.5	8.42	7.75	6.56	11,146	12,096	14,300	3,610,000	7,740	8,400	154.1	11,230
134	No. 15	293.0	259.6	234.2	314.0	278.2	250.9	7.61	6.74	6.09	11,651	13,154	14,580	3,413,000	8,610	9,720	144.1	11,290
137	No. 15	281.0	249.0	224.7	302.6	268.1	241.9	7.30	6.47	5.83	11,651	13,154	14,580	3,275,000	8,300	9,365	145.7	10,230
130	No. 16	322.0	297.0	258.6	345.8	319.0	277.7	8.36	7.72	6.72	11,592	12,569	14,440	3,732,000	7,440	8,070	136.7	11,480
133	No. 18B	287.5	255.5	235.5	309.3	274.9	253.4	7.47	6.64	6.12	12,031	13,536	14,690	3,460,000	8,600	9,690	154.7	10,820
135	No. 18B	327.0	287.4	265.0	351.1	308.6	284.6	8.50	7.47	6.88	11,952	13,599	14,750	3,909,000	7,740	8,800	152.6	10,950

[a] The calorific value of the gas is given according to the high heat value.

[b] Mixed with 50 per cent "front-end" cinders from locomotives in test 33 and with 33⅓ per cent of the same cinders in test 34.

[c] Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Fuel charged per hour (pounds).									Calorific value (British thermal units).							
		In producer.			In producer plant.			Per square foot of fuel-bed area.			Fuel.				Standard gas (at 62° F. and 14.7 pound pressure).			
											Per pound.			Per hour as fired.	Per pound of fuel.		Per cubic foot.	Per brake-horsepower hour.
		As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.		As fired.	Dry.		
1	2	21	22	23	24	25	26	27	28	29	37	38	39	40	41	42	43	45
	Indian Territory:																	
1	No. 1	361.0	344.0	312.0	392.7	374.0	339.3	9.38	8.94	8.11	12,787	13,455	14,800	4,620,000	8,215	8,620	159.2	12,080
20	No. 4	278.0	253.	207.8	312.5	284.6	233.6	7.23	6.59	5.40	10,364	11,392	13,890	2,885,000	9,086	9,980	161.1	10,750
22	Iowa: No. 2	362.5	302.	227.5	408.4	340.7	256.2	9.43	7.87	5.92	8,735	10,489	13,950	3,175,000	7,770	9,300	160.2	12,130
	Kansas:																	
24	No. 5	307.8	294.3	259.8	338.4	323.6	285.7	8.00	7.65	6.77	12,836	13,421	15,200	3,950,000	10,050	10,500	167.2	13,130
25	No. 5	288.3	276.0	246.7	325.3	311.4	278.3	7.50	7.18	6.41	12,967	13,541	15,160	3,740,000	8,510	8,890	128.9	10,030
101	No. 6	329.2	296.8	253.1	349.4	315.0	268.7	8.55	7.71	6.58	11,470	12,721	14,910	3,773,000	8,250	9,170	155.2	11,620
	Kentucky:																	
79	No. 1B	261.0	254.2	245.4	276.7	269.5	260.2	6.78	6.60	6.38	14,270	14,652	15,180	3,728,000	......	......	166.5	......
12	No. 3	370.0	343.3	310.0	410.8	381.2	344.2	9.61	8.92	8.06	12,283	13,226	14,650	4,540,000	7,982	8,590	155.9	12,540
81	No. 5	258.0	248.2	237.8	274.4	263.9	252.9	6.70	6.45	6.18	13,984	14,530	15,170	3,609,000	10,840	11,260	163.2	12,000
85	No. 6	252.0	240.6	237.0	265.6	253.6	244.6	6.55	6.25	6.03	13,747	14,391	14,930	3,462,000	11,200	11,800	176.0	12,100
84	No. 7	306.0	280.0	251.0	322.8	295.4	264.8	7.95	7.27	6.52	11,986	13,093	14,600	3,665,000	8,450	9,240	153.7	11,250
97	Massachusetts: No. 1	720.0	361.0	275.0	......	......	......	18.70	9.37	7.14	4,241	8,447	11,120	3,055,000	4,300	8,580	166.6	13,160
	Missouri:																	
7A	No. 2	522.0	462.0	384.0	579.4	512.8	426.3	13.60	12.00	10.00	10,505	11,882	14,280	5,490,000	5,492	6,200	135.6	12,200
7B	No. 2	346.5	306.0	255.0	384.5	339.6	283.0	9.00	7.96	6.62	10,505	11,882	14,280	3,640,000	7,798	8,820	140.0	11,560
	Montana:																	
5A	No. 1	456.5	404.5	355.8	506.8	449.1	395.0	11.85	10.50	9.25	10,575	11,934	13,580	4,825,000	5,820	6,580	160.8	11,340
5B	No. 1	386.0	342.0	300.0	425.3	376.8	330.6	10.00	8.90	7.80	10,575	11,934	13,580	4,080,000	5,770	6,515	127.7	14,150
149	No. 2	386.3	353.5	294.0	424.6	388.5	323.1	10.04	9.18	7.64	10,478	11,452	13,770	4,050,000	6,760	7,400	147.5	11,770
150	No. 3	325.6	297.9	254.2	347.2	317.6	271.0	8.46	7.74	6.61	10,685	11,686	13,690	3,480,000	7,830	8,570	181.5	10,860
	New Mexico:																	
121	No. 3A	257.0	247.8	197.3	275.7	265.8	211.6	6.68	6.44	5.12	11,425	11,853	14,890	2,938,000	10,250	10,620	155.1	11,270
122	No. 4A	262.2	255.8	220.3	287.5	280.5	241.6	6.81	6.65	5.72	12,501	12,812	14,880	3,278,000	8,250	8,460	135.3	9,700
120	No. 5	277.8	272.8	229.8	298.1	292.7	246.6	7.22	7.08	5.97	12,542	12,769	15,170	3,482,000	10,200	10,390	159.6	12,210

	North Dakota:																
68	No. 1B	530.5	357.3	296.9	559.5	376.8	313.1	13.79	9.28	7.71	6,970	10,346	12,460	3,700,000	4,680	6,945	160.6	10,630
10	No. 2	460.0	278.0	249.0	510.0	308.0	275.8	12.00	7.23	6.48	6,802	11,255	12,600	3,129,000	4,750	7,830	188.5	13,770
72	No. 2B	520.0	332.2	305.9	552.1	352.7	324.8	13.50	8.63	7.95	7,326	11,473	12,450	3,810,000	....	....	164.1	....
152	No. 2B	533.5	325.9	297.1	571.6	349.2	318.3	13.86	8.46	7.72	6,739	11,034	12,100	3,595,000	4,725	7,740	145.0	10,750
67	No. 3	605.0	388.4	349.4	632.8	406.3	365.5	15.72	10.09	9.08	7,279	11,335	12,600	4,403,000	4,155	6,470	158.9	10,920
	Ohio:																
64	No. 3[a]	285.0	261.9	239.7	303.4	278.8	255.2	7.41	6.81	6.23	12,200	13,279	14,520	3,479,000	9,380	10,200	156.1	11,300
60	No. 4	252.0	239.2	220.1	270.4	256.6	236.1	6.56	6.22	5.73	13,158	13,855	15,060	3,318,000	10,510	11,070	148.8	11,120
58	No. 5	237.0	226.8	212.7	254.0	243.1	228.0	6.16	5.90	5.53	13,414	14,031	14,960	3,180,000	11,040	11,550	152.3	11,000
76	No. 6	237.0	228.4	207.9	254.2	245.0	223.0	6.16	5.94	5.40	13,035	13,523	14,860	3,090,000	11,460	11,900	163.4	11,800
87	No. 7	313.5	296.8	271.2	331.0	313.4	286.4	8.14	7.71	7.05	12,841	13,558	14,830	4,025,000	8,610	9,100	156.2	11,590
83	No. 8	297.0	271.2	235.3	309.1	282.3	244.9	7.72	7.05	6.12	11,302	12,379	14,270	3,360,000	9,420	10,300	170.2	11,960
73	No. 9A	256.0	237.6	216.5	277.7	257.7	234.8	6.65	6.17	5.63	12,492	13,466	14,780	3,199,000	....	....	154.6	....
142	No. 10	253.0	242.8	220.2	268.7	257.9	233.9	6.57	6.31	5.72	12,805	13,345	14,720	3,240,000	10,420	10,860	165.6	11,270
145	No. 11	277.0	267.4	231.5	296.8	286.5	248.1	7.19	6.95	6.02	12,287	12,724	14,690	3,400,000	9,330	9,670	165.2	11,100
146	No. 12	313.2	304.0	272.9	335.5	325.6	292.3	8.14	7.90	7.09	12,933	13,329	14,860	4,052,000	8,550	8,800	164.8	11,430
147	No. 12	287.0	276.0	244.4	309.3	297.4	263.4	7.46	7.17	6.35	12,739	13,244	14,940	3,654,000	8,800	9,160	164.6	10,820
	Pennsylvania:																
65	No. 4	264.0	259.2	230.1	276.6	271.6	241.1	6.86	6.74	5.98	13,518	13,761	15,500	3,568,000	9,680	9,860	140.6	11,120
59	No. 5B	243.0	234.8	216.0	259.0	250.6	230.5	6.32	6.11	5.62	13,613	14,097	15,330	3,310,000	10,175	10,530	149.3	10,340
66	No. 6[a]	276.8	270.8	249.3	294.8	288.4	265.5	7.19	7.03	6.48	13,921	14,225	15,430	3,850,000	8,130	8,310	126.6	9,780
70	Nos. 6A and 6B	225.0	218.6	191.8	238.3	231.5	203.1	5.85	5.68	4.98	13,025	13,406	15,290	2,930,000	10,700	11,020	146.4	10,540
88	No. 7	267.0	257.8	224.0	284.5	274.7	238.7	6.94	6.69	5.82	13,223	13,707	15,770	3,531,000	8,830	9,150	139.4	11,780
63	No. 8	222.0	216.6	200.6	240.0	234.2	216.9	5.77	5.63	5.22	14,353	14,720	15,900	3,189,000	11,640	11,940	133.0	11,690
71	No. 10	246.0	239.0	218.2	258.6	251.2	229.4	6.39	6.21	5.67	13,306	13,991	15,330	3,348,000	10,120	10,400	159.5	10,770
129	No. 11	244.0	239.4	221.6	265.0	260.0	240.7	6.34	6.22	5.76	13,775	14,049	15,170	3,362,000	10,480	10,680	146.4	12,730
143	No. 12	217.9	213.6	193.5	240.2	235.4	213.3	5.66	5.55	5.03	13,622	13,894	15,340	2,968,000	11,800	12,040	147.5	11,180
136	No. 13	252.0	245.4	212.2	274.5	267.4	231.2	6.54	6.38	5.51	12,816	13,167	15,220	3,230,000	9,890	10,150	153.0	10,950
140	No. 13	235.0	231.0	202.6	255.8	251.5	220.6	6.11	6.00	5.26	13,181	13,405	15,290	3,099,000	10,900	11,100	144.9	11,080
144	No. 15	237.5	231.5	207.0	263.3	256.6	229.4	6.17	6.02	5.38	13,712	14,072	15,740	3,258,000	10,970	11,260	144.4	11,560
148	No. 16	199.0	188.5	172.5	223.0	211.2	193.3	5.17	4.90	4.48	13,318	14,067	15,360	2,650,000	12,820	13,540	149.5	10,900
158	No. 17	264.0	252.4	218.8	279.9	267.6	232.0	6.86	6.55	5.68	12,798	13,387	15,435	3,379,000	9,060	9,470	141.2	10,790
159	No. 22	234.0	224.6	200.8	248.5	238.5	213.2	6.08	5.83	5.22	13,311	13,864	15,500	3,115,000	10,680	11,120	145.6	10,740
113	Rhode Island: No. 1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Tennessee:																
115	No. 1	246.0	239.4	209.2	262.9	255.8	223.6	6.39	6.22	5.44	12,749	13,108	15,000	3,139,000	....	....	154.5	....
107	No. 2	225.0	217.4	206.7	248.9	240.5	228.7	5.85	5.65	5.37	13,882	14,371	15,110	3,123,000	13,020	13,470	167.9	12,360
106	No. 3	259.0	246.4	229.0	281.3	267.6	248.7	6.73	6.40	5.95	13,156	13,828	14,880	3,410,000	10,940	11,500	159.7	11,980
111	No. 4	243.0	235.0	217.0	263.9	255.2	235.6	6.32	6.10	5.64	13,379	13,835	14,990	3,253,000	11,060	11,430	161.7	12,570
125	No. 5	258.0	251.6	228.7	281.2	274.3	249.3	6.70	6.54	5.94	13,442	13,793	15,170	3,469,000	10,040	10,290	142.1	11,790
110	No. 6	265.0	255.7	201.1	291.2	280.9	221.0	6.89	6.64	5.23	11,621	12,049	15,320	3,080,000	8,720	9,030	133.3	12,580
108	No. 7A	288.0	279.4	242.3	313.6	304.3	263.8	7.48	7.26	6.30	12,602	12,996	14,990	3,631,000	9,810	10,110	154.6	12,470
116	Nos. 8A and 8B[a]	225.0	221.4	197.5	243.9	240.0	214.1	5.85	5.75	5.13	13,471	13,693	15,330	3,030,000	....	....	147.4	....
119	Nos. 8A and 8B[a]	273.0	266.2	239.5	291.3	284.1	255.6	7.09	6.92	6.22	13,459	13,793	15,340	3,675,000	10,580	10,850	157.5	12,460
	Texas:																
11	No. 1	590.0	393.0	332.0	660.0	439.5	371.3	15.36	10.22	8.64	7,267	10,928	12,945	4,295,000	4,743	7,130	167.0	12,040
18	No. 2	468.0	310.3	276.2	519.5	344.4	306.6	12.20	8.07	7.18	7,348	11,086	12,450	3,440,000	5,342	8,060	156.2	10,570
93	No. 3	510.0	345.8	300.5	549.4	372.5	323.7	13.25	8.98	7.81	7,603	11,214	12,900	3,879,000	5,490	8,100	171.8	11,880
92	No. 4	491.0	323.6	287.0	529.8	349.2	309.7	12.76	8.40	7.46	7,448	11,297	12,730	3,658,000	....	....	156.1	....

[a] Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Fuel charged per hour (pounds).									Calorific value (British thermal units).							
		In producer.			In producer plant.			Per square foot of fuel-bed area.			Fuel.				Standard gas (at 62° F. and 14.7 pound pressure).			
											Per pound.			Per hour as fired.	Per pound of fuel.		Per cubic foot.	Per brake-horse-power hour.
		As fired.	Dry.	Combusti-ble.	As fired.	Dry.	Combusti-ble.	As fired.	Dry.	Combusti-ble.	As fired.	Dry.	Combusti-ble.		As fired.	Dry.		
1	**2**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**45**
118	Utah: No. 1	285.0	268.4	255.1	302.0	284.4	270.3	7.40	6.98	6.62	13,212	14,027	14,770	3,767,000	10,160	10,780	171.4	11,930
	Virginia:																	
77	No. 1	282.0	265.8	247.6	300.2	283.0	263.6	7.32	6.90	6.43	13,324	14,130	15,170	3,756,000	9,690	10,280	164.4	11,830
78	No. 2	259.0	252.8	237.7	272.7	266.1	250.2	6.73	6.56	6.17	14,080	14,420	15,330	3,645,000	....	....	169.0	....
75	No. 3	221.0	217.2	206.3	236.7	232.7	221.0	5.74	5.64	5.36	14,643	14,890	15,675	3,235,000	11,820	12,020	156.4	11,390
74	No. 4	244.0	237.4	230.6	257.0	250.1	242.9	6.34	6.17	6.00	14,470	14,875	15,310	3,530,000	....	....	167.2	....
154	No. 5A	265.0	256.4	208.0	287.3	277.9	225.7	6.88	6.66	5.41	12,159	12,578	15,490	3,223,000	9,050	9,360	160.7	10,220
160	No. 6	220.0	210.2	188.0	240.8	230.1	205.8	5.71	5.46	4.88	13,351	13,981	15,630	2,939,000	10,820	11,320	138.1	10,470
163	Jamestown No. 1	244.0	241.0	203.0	300.3	296.6	249.9	4.96	4.90	4.12	12,641	12,805	15,165	3,084,400	11,304	11,438	154.0	11,540
	Washington:																	
90	No. 1A[a]	472.5	396.3	336.9	496.3	416.2	353.8	12.27	10.29	8.75	9,787	11,675	13,740	4,629,000	4,850	5,780	145.9	13,500
89	No. 1B	411.2	344.8	289.8	440.7	369.5	310.6	10.68	8.96	7.53	9,680	11,554	13,750	3,980,000	6,230	7,435	159.2	13,950
94	No. 1B	468.0	393.0	328.0	506.0	424.9	354.6	12.15	10.21	8.52	9,634	11,473	13,750	4,510,000	5,510	6,560	144.1	11,190
112	No. 2	265.9	255.1	218.2	281.8	270.3	231.2	6.91	6.63	5.68	12,218	12,730	14,890	3,249,000	9,790	10,190	168.6	11,300
	West Virginia:																	
3	No. 1	287.5	283.0	265.5	320.6	315.6	296.1	7.47	7.36	6.91	14,166	14,396	15,350	4,075,000	9,130	9,260	144.4	11,130
4	No. 4	233.0	229.0	208.0	262.8	258.2	234.5	6.05	5.96	5.40	13,918	14,202	15,600	3,250,000	11,390	11,610	143.2	11,320
23	No. 7	264.9	256.9	239.1	299.2	290.2	270.1	6.88	6.68	6.22	14,283	14,720	15,800	3,780,000	12,720	13,140	154.2	14,380
19	No. 8	328.6	320.1	301.1	364.7	355.1	334.1	8.54	8.32	7.84	14,168	14,558	15,470	4,660,000	8,825	9,070	155.1	12,340
17A	No. 9	244.0	237.5	223.5	273.9	265.6	250.0	6.34	6.18	5.81	14,195	14,580	15,500	3,465,000	9,750	10,000	150.9	12,000
17B	No. 9	300.0	292.0	274.9	328.9	320.1	301.4	7.80	7.60	7.15	14,195	14,580	15,500	4,260,000	7,945	8,150	151.0	10,060
21	No. 9	250.0	244.5	227.0	284.8	278.5	258.6	6.50	6.36	5.90	14,224	14,548	15,650	3,555,000	11,125	11,380	160.5	11,860
161	No. 11B	378.0	376.2	210.9	....	....	....	9.82	9.77	5.48	8.566	8,606	15,350	3.237,600	6,340	6,375	144.0	10,480
8	No. 12	270.0	266.1	248.7	304.9	300.5	280.9	7.01	6.92	6.47	14,614	14,825	15,860	3,945,000	10,010	10,150	142.5	11,500
56	No. 13	195.0	189.8	182.9	208.0	202.4	195.1	5.07	4.94	4.76	14,674	15,073	15,640	2,862,000	14,020	14,400	139.2	11,580
54	No. 14	207.3	201.0	195.5	220.6	213.9	208.0	5.40	5.23	5.09	14,488	14,954	15,380	3,005,000	13,220	13,640	147.0	11,570
86	No. 16A	263.0	257.0	238.8	277.5	271.2	252.0	6.83	6.68	6.19	13,882	14,206	15,290	3,650,000	10,010	10,250	156.1	11,270

80	No. 18	225.0	218.8	205.9	238.0	231.5	217.8	5.74	5.68	5.35	14,152	14,537	15,460	3,184,000	....	....	158.9	....
82	No. 20	243.0	238.6	220.1	257.3	252.6	233.1	6.32	6.20	5.72	13,948	14,206	15,400	3,390,000	11,630	11,850	156.3	12,230
162	No. 24	220.0	213.6	151.8	....	....	....	5.72	5.55	3.94	10,545	10,861	15,280	2,320,000	8,170	8,420	106.3	10,270
156	No. 25	260.0	250.0	228.6	273.0	262.5	240.0	6.75	6.49	5.94	13,288	13,817	15,110	3,456,000	9,330	9,710	171.6	10,350
164	Jamestown No. 3	220.0	217.0	200.5	261.2	257.6	238.0	6.72	6.63	6.13	14,420	14,618	15,820	3,172,400	11,648	11,814	138.5	10,850
165	Jamestown No. 4	214.3	210.9	199.3	246.3	242.4	229.1	6.54	6.44	6.08	14,636	14,877	15,743	3,136,500	12,045	12,233	150.0	10,780
166	Jamestown No. 5	210.2	206.2	192.6	237.2	232.7	217.4	6.42	6.29	5.88	14,333	14,618	15,651	3,012,800	12,566	12,817	152.5	11,230
167	Jamestown No. 7	234.3	230.4	217.6	260.4	256.1	241.9	7.15	7.04	6.64	14,665	14,915	15,793	3,436,000	11,788	11,990	152.3	11,976
168	Jamestown No. 7	217.7	214.0	202.2	243.9	239.8	226.6	6.65	6.53	6.17	14,665	14,915	15,793	3,193,000	12,559	12,782	154.1	11.600
	Wyoming:																	
16	No. 2	403.3	365.3	281.6	459.8	416.5	321.1	10.50	9.50	7.30	9,650	10,656	13,820	3,891,400	5,590	6,168	151.0	9,516
62	No. 2B	416.2	380.5	290.0	440.2	402.5	306.7	10.80	9.90	7.50	9,853	10,784	14,150	4,103,000	6,100	6,680	146.6	11,200
69	No. 3	370.1	322.0	265.1	394.5	343.2	282.6	9.62	8.36	6.89	9,338	10,737	13,050	3,460,000	7,150	8,230	160.9	11,660
123	No. 4	404.0	358.4	328.8	438.2	388.8	356.7	10.50	9.30	8.50	10,755	12,127	13,220	4,345,000	....	....	151.6	....
114	No. 5	312.0	276.2	264.6	....	....	....	8.10	7.18	6.88	11,747	13,262	13,840	3,665,000	8,690	9,820	168.0	11,850
124	No. 6	438.0	358.0	346.0	474.9	388.2	375.1	11.40	9.30	9.00	10,460	12,798	13,250	4,580,000	....	....	171.8	....
	Miscellaneous:																	
151	Coke	....	....	....	....	....	....	....	....	....	11,475	12,454	14,230	....	....	....	120.6	....
50	Coke breeze	393.3	340.3	283.7	....	....	....	10.24	8.86	7.38	10,213	11,801	14,170	4,020,000	7,070	8,175	136.9	12,230
153	Refuse	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

a Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	British thermal units equivalent to stated horsepower per minute.				Production of gas (cubic feet).									Standard gas consumed per horsepower hour (cubic feet).		
						Meter per hour.	Standard gas (at 62° F. and 14.7 pounds pressure).										
							Total.	Per hour.	Per pound of fuel charged.								
									In producer.			Total used by producer plant.					
		Gas.	Indicated.	Brake.	Electrical.				As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	Indicated.	Brake.	Electrical.
1	2	47	48	49	50	51	52	53	54	55	56	57	58	59	61	62	63
	Alabama:																
2	No. 2	41,700	12,435	9,985	8,500	17,980	775,500	18,950	58.1	60.4	67.0	52.9	55.0	60.9	59.6	74.2	87.4
109	No. 4	46,510	....	9,730	8,270	19,160	441,290	18,380	75.4	77.8	89.4	69.3	71.6	82.2	....	80.0	94.2
155	No. 6	40,500	....	9,920	8,420	17,050	846,055	16,920	70.5	72.3	77.8	66.0	67.6	72.7	....	72.3	85.1
	Argentina:																
141	Argentina (special)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
169	Jamestown No. 8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Arkansas:																
96	No. 7A	39,550	....	6,845	5,820	19,120	945,850	18,920	73.3	76.6	87.8	67.5	70.6	80.8	....	117.1	137.8
95	No. 8	44,100	....	8,840	7,515	20,910	529,195	20,360	61.9	63.6	75.8	56.8	58.5	69.6	....	97.6	114.8
91	No. 10	25,130	....	6,425	5,455	11,730	216,975	12,050	26.3	43.4	51.7	23.0	38.0	45.3	....	79.5	93.6
44	Brazil: No. 1	35,420	9,880	7,080	6,015	16,860	390,135	16,250	48.2	54.1	73.4	44.0	49.5	67.1	69.7	97.3	114.5
	California:																
32	No. 1	48,000	....	10,340	8,800	19,380	764,810	18,200	32.1	38.8	47.7	30.5	36.9	45.4	....	74.6	87.7
33	No. 1 [a]	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
34	No. 1 [a]	43,220	....	10,280	8,750	20,860	469,185	19,550	39.6	45.5	55.4	....	....	....	....	80.6	94.7
15	Colorado: No. 1	38,070	11,460	9,985	8,485	15,183	460,300	15,343	42.1	52.8	57.0	35.8	44.9	48.5	56.7	65.1	76.7
117	Florida: No. 1	51,600	....	10,230	8,690	18,280	[b] 424,840	17,690	30.3	38.3	41.0	28.5	36.1	38.6	....	73.3	86.3
	Illinois:																
6	No. 3	44,910	11,365	9,980	8,460	17,607	522,350	17,412	49.8	53.9	60.2	45.1	48.8	54.5	64.8	73.9	87.1
9	No. 4	45,250	10,890	9,875	8,410	17,712	536,435	17,881	51.1	58.4	65.3	44.9	51.4	57.4	69.6	76.7	90.0
35	No. 6B	45,800	12,800	10,300	8,760	19,180	1,084,220	18,070	46.4	52.4	64.1	43.2	48.9	59.8	59.9	74.4	87.4
26	No. 7A	31,550	....	6,915	5,880	17,960	196,610	17,320	....	....	....	....	....	....	....	106.1	124.9
27	No. 7B	45,200	....	10,190	8,660	20,270	587,540	19,580	43.1	48.8	60.9	39.8	45.2	56.4	....	81.5	95.9
38	No. 7C	39,600	12,050	8,725	7,420	20,970	652,965	19,780	41.5	46.2	58.5	38.9	43.3	54.9	69.5	96.1	113.0
29	No. 8	45,600	....	10,370	8,820	19,050	781,730	18,610	48.7	55.9	64.5	45.3	51.9	59.9	....	76.0	89.4

28	No. 9B	45,400	....	10,380	8,820	19,639	1,137,470	18,958	48.0	54.6	62.7	45.4	51.6	59.3	....	77.4	91.1
31	No. 10	45,350	....	10,360	8,800	20,440	978,850	19,580	62.8	68.7	77.8	59.4	65.0	73.7	....	80.2	94.4
30	No. 11A	48,850	....	10,470	8,900	18,590	934,700	17,630	60.5	65.0	73.8	57.7	62.0	70.4	....	71.4	83.9
36	No. 11C[b]	39,050	11,300	8,680	7,380	22,600	512,100	21,330	....	....	....	....	....	....	80.1	104.3	122.6
42	No. 11D[b]	43,350	12,480	10,030	8,525	20,080	946,220	18,925	75.1	82.3	89.5	68.3	74.9	81.3	64.3	80.0	94.1
48	No. 11D[b]	....	12,510	10,100	8,856	....	....	....	....	....	....	....	....	....	....	....	....
41	No. 13	42,210	13,560	10,410	8,850	19,570	915,880	18,320	54.1	59.2	66.7	50.6	55.4	62.4	57.2	74.6	87.8
37	No. 14	43,100	12,320	9,920	8,440	18,114	858,610	17,172	51.6	59.1	68.8	48.3	55.3	64.4	59.1	73.4	86.3
39	No. 15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
40	No. 15	45,550	12,350	10,600	8,510	20,210	956,430	19,130	56.4	62.3	73.2	53.1	58.6	70.0	65.6	81.0	95.4
43	No. 16	44,900	12,840	10,050	8,530	19,165	902,600	18,050	52.3	56.7	63.9	49.6	53.7	60.5	59.6	76.3	89.7
45	No. 18	43,850	12,680	10,060	8,550	18,920	890,690	17,814	55.0	63.4	71.7	[illegible]	58.6	66.3	59.6	75.0	88.3
55	No. 19B	47,600	12,960	10,040	8,520	18,510	871,600	17,430	62.5	69.1	77.2	59.2	65.4	73.1	57.0	73.6	86.6
128	No. 19C	39,280	....	7,040	5,980	18,320	547,075	17,100	59.4	65.8	74.2	54.4	60.3	68.0	....	102.9	121.2
105	No. 21	47,250	....	9,560	8,130	18,410	8,432,296	18,170	49.1	57.5	66.4	45.9	53.8	62.1	....	80.5	94.7
102	No. 22A	45,800	....	9,810	8,330	17,310	810,745	17,250	49.7	56.1	65.9	46.9	52.8	62.1	....	74.5	87.7
98	No. 23A	43,750	....	9,900	8,410	18,120	887,995	17,760	49.4	56.0	64.7	46.9	53.2	61.5	....	76.1	89.5
100	No. 23B[c]	42,300	....	9,050	7,695	17,710	875,915	17,520	50.8	59.6	66.7	46.7	54.8	61.4	....	82.0	96.5
103	No. 24B	42,050	....	10,000	8,500	16,500	786,455	15,730	53.7	60.6	69.0	50.5	57.0	64.8	....	66.6	78.4
104	No. 25	40,680	....	10,000	8,505	14,730	727,235	14,540	45.5	51.3	60.5	43.1	48.6	57.3	....	61.6	72.5
126	No. 26	43,050	....	8,710	7,400	18,920	877,815	17,560	54.7	63.1	77.3	50.4	58.2	71.2	....	85.4	100.5
127	No. 27	34,500	....	6,235	5,295	17,970	845,415	16,910	52.7	59.4	70.5	48.7	55.0	65.1	....	114.9	135.4
139	No. 29B	....	....	9,695	8,235	....	....	....	....	....	....	....	....	....	....	....	....
157	No. 30[c]	40,600	....	9,920	8,440	15,830	789,865	15,800	48.8	51.6	57.5	46.5	49.3	54.9	....	67.5	79.3
	Indiana:																
14	No. 1	44,980	11,465	9,980	8,475	17,710	521,100	17,560	44.5	50.3	56.7	40.4	45.6	51.5	64.9	74.7	87.8
13A	No. 2	36,880	10,285	8,310	7,060	16,400	333,000	15,860	48.3	52.8	59.2	42.8	46.9	52.5	65.3	80.9	95.1
13B	No. 2	46,320	11,510	10,625	8,520	18,200	122,160	17,450	58.2	63.6	71.3	51.6	55.9	62.6	64.3	73.8	86.8
53	No. 3[c]	41,650	12,250	9,470	8,050	20,080	912,545	18,250	52.0	59.0	65.1	49.0	55.6	61.3	63.1	81.7	96.1
46	No. 5	41,100	12,540	9,930	8,440	19,020	541,750	18,060	45.8	50.8	59.1	42.3	47.0	54.6	61.0	77.1	90.7
47	No. 5	41,000	....	10,030	8,580	17,950	848,550	16,970	59.5	66.6	75.3	55.7	62.3	70.5	....	71.3	83.9
49	No. 6	....	....	9,970	8,460	....	....	....	....	....	....	....	....	....	....	....	....
51	No. 7A	42,300	....	9,890	8,400	17,200	721,760	16,030	52.8	57.3	64.7	49.1	53.2	60.2	....	68.7	80.9
57	No. 8	44,000	....	10,030	8,495	19,250	872,545	17,450	57.0	62.9	71.8	54.1	59.6	68.1	....	74.0	87.1
52	No. 9A	45,600	12,660	9,780	8,300	19,260	811,450	18,030	52.5	60.1	67.9	50.0	57.2	64.6	60.4	78.2	92.0
61	No. 11	42,800	12,600	10,000	8,490	18,390	569,690	17,450	54.8	62.9	69.6	50.4	57.9	64.0	58.7	74.0	87.1
99	No. 12	44,550	....	9,700	8,240	17,720	894,995	17,900	52.0	58.1	67.6	49.1	54.8	63.8	....	78.2	92.0
132	No. 13	37,350	....	7,980	6,780	18,380	850,545	17,010	55.6	62.8	73.9	51.0	57.6	67.9	....	90.4	106.2
138	No. 13	....	....	9,465	8,045	....	....	....	....	....	....	....	....	....	....	....	....
131	No. 14	41,750	....	9,465	8,050	17,360	813,400	16,270	50.2	54.5	64.5	47.4	51.5	60.8	....	72.9	85.7
134	No. 15	41,990	....	9,470	8,040	18,820	856,775	17,500	59.8	67.4	74.7	55.8	62.9	69.8	....	78.3	92.2
137	No. 15	38,800	....	9,670	8,220	16,490	799,915	16,000	57.0	64.3	71.2	52.9	59.7	66.2	....	70.1	82.5
130	No. 16	39,900	....	8,855	7,520	18,870	876,670	17,530	54.5	59.0	67.8	50.7	55.0	63.2	....	83.9	98.8
133	No. 18B	41,200	....	9,700	8,250	17,670	576,015	16,000	55.7	62.6	67.9	51.7	58.2	63.1	....	69.9	82.2
135	No. 18B	42,100	....	9,800	8,320	17,480	762,360	16,570	50.7	57.6	62.5	47.2	53.7	58.2	....	71.7	84.3
	Indian Territory:																
1	No. 1	48,340	12,990	10,170	8,650	18,990	577,000	18,613	51.6	54.1	59.4	47.4	49.9	54.6	59.5	75.9	91.4
20	No. 4	42,020	11,610	9,960	8,460	15,480	355,280	15,680	56.4	61.9	75.5	50.2	55.1	67.1	57.2	66.7	78.5
22	Iowa: No. 2	46,860	11,660	9,850	8,375	17,820	234,110	17,570	48.5	58.1	77.2	43.0	51.6	68.5	63.9	75.6	88.9

[a] Mixed with 50 per cent "front-end" cinders from locomotives in test 33, and with 33⅓ per cent of the same cinders in test 34.

[b] 24 hours.

[c] Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	British thermal units equivalent to stated horsepower per minute.				Production of gas (cubic feet).										Standard gas consumed per horsepower hour (cubic feet).		
						Meter per hour.	Standard gas (at 62° F. and 14.7 pounds pressure).											
		Gas.	Indicated.	Brake.	Electrical.		Total.	Per hour.	Per pound of fuel charged.							Indicated.	Brake.	Electrical.
									In producer.			Total used by producer plant.						
									As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.				
1	2	47	48	49	50	51	52	53	54	55	56	57	58	59		61	62	63
	Kansas:																	
24	No. 5	51,500	10,830	9,985	8,490	18,500	240,310	18,490	60.1	62.8	71.2	54.6	57.2	64.8		72.4	78.5	92.4
25	No. 5	40,850	12,890	10,370	8,820	20,487	570,810	19,027	66.0	69.0	77.2	58.5	61.1	68.4		62.6	77.5	91.5
101	No. 6	45,300	....	9,920	8,435	17,900	239,600	17,520	53.2	59.1	69.3	50.1	55.6	65.3		....	74.8	88.0
	Kentucky:																	
79	No. 1B	....	....	9,820	8,350	....	....	....	....	....	....	....	....	....		....	....	....
12	No. 3	49,170	11,635	9,985	8,500	18,947	568,295	18,943	51.2	55.1	61.1	46.2	49.7	55.0		69.0	80.4	94.6
81	No. 5	46,580	....	9,900	8,410	17,350	856,350	17,130	66.4	69.0	72.1	62.4	64.9	67.8		....	73.4	86.4
85	No. 6	47,300	....	9,960	8,460	15,920	806,285	16,130	64.0	67.0	69.5	60.7	63.6	65.9		....	68.7	80.9
84	No. 7	43,100	....	9,760	8,290	16,400	841,725	16,830	55.0	60.1	67.1	52.2	57.0	63.6		....	73.2	86.1
97	Massachusetts: No. 1	51,600	....	9,980	8,480	19,440	167,385	18,600	25.8	51.5	67.6	....	....	....		....	78.9	92.9
	Missouri:																	
7A	No. 2	47,620	12,085	9,925	8,435	21,600	133,579	21,100	40.5	45.8	55.0	36.4	41.2	49.5		74.0	90.1	106.0
7B	No. 2	44,970	11,340	9,900	8,420	19,690	83,545	19,300	55.7	63.0	75.7	50.2	56.8	68.2		72.1	82.6	97.1
	Montana:																	
5A	No. 1	44,300	11,715	9,950	8,460	16,800	369,500	16,550	36.2	40.9	46.5	32.6	36.8	41.9		59.8	70.5	82.9
5B	No. 1	37,140	9,495	6,675	5,675	17,694	81,500	17,464	45.2	51.0	58.2	41.1	46.3	52.8		77.9	110.9	130.5
149	No. 2	43,500	....	9,420	8,010	17,540	708,355	17,720	45.9	50.1	60.3	41.7	45.6	54.8		....	79.7	93.8
150	No. 3	42,500	....	9,960	8,460	14,280	687,865	14,050	43.2	47.2	55.3	40.5	44.3	51.9		....	59.8	70.4
	New Mexico:																	
121	No. 3A	43,800	....	9,900	8,410	18,050	847,975	16,960	66.0	68.5	86.0	61.6	63.8	80.2		....	72.6	85.5
122	No. 4A	36,050	....	9,460	8,040	17,440	799,350	15,990	61.0	62.5	72.6	55.6	57.0	66.2		....	71.6	84.3
120	No. 5	47,180	....	9,840	8,360	18,980	798,790	17,750	63.9	65.2	77.3	59.6	60.7	72.0		....	76.5	90.0
	North Dakota:																	
68	No. 1B	41,350	....	9,900	8,410	15,950	757,250	15,450	29.2	43.3	52.1	27.6	41.0	49.4		....	66.1	77.8

10	No. 2	36,210	8,190	6,700	5,690	11,454	346,400	11,550	25.2	41.5	46.4	22.7	37.5	41.9	59.7	73.0	85.9
72	No. 2B	....	....	9,752	8,289	....	....	....	....	....	....	....	....	....	....	....	....
152	No. 2B	41,960	....	9,940	8,440	17,370	208,700	17,370	32.6	53.3	58.5	30.4	49.8	54.6	....	74.1	87.2
67	No. 3	41,850	....	9,755	8,290	16,530	790,620	15,810	26.1	40.7	45.3	25.0	38.9	43.3	....	68.7	80.8
	Ohio:																
64	No. 3 [a]	44,500	11,590	10,020	8,520	17,930	855,350	17,110	60.1	65.4	71.5	56.4	61.4	67.1	62.6	72.4	85.3
60	No. 4	44,100	12,680	10,100	8,580	18,700	445,070	17,800	70.7	74.5	80.9	65.8	69.4	75.4	59.5	74.7	87.9
58	No. 5	43,600	12,750	10,100	8,580	18,040	858,815	17,180	72.5	75.8	80.8	67.6	70.6	75.4	57.1	72.2	84.9
76	No. 6	45,300	....	9,760	8,300	17,050	831,820	16,640	70.2	72.8	80.0	65.4	67.9	74.6	....	72.3	85.1
87	No. 7	45,000	....	9,880	8,400	17,150	708,560	17,280	55.1	58.3	63.7	52.2	55.1	60.3	....	74.2	87.3
83	No. 8	46,580	....	9,920	8,420	16,140	820,995	16,420	55.3	60.6	69.8	53.1	58.2	67.1	....	70.2	82.7
73	No. 9A	....	....	9,710	8,247	....	....	....	....	....	....	....	....	....	....	....	....
142	No. 10	43,900	....	9,930	8,440	16,320	795,760	15,920	62.9	65.5	72.3	59.3	61.7	68.1	....	68.0	80.0
145	No. 11	43,050	....	9,955	8,460	15,880	781,580	15,640	56.5	58.5	67.6	52.7	54.6	63.0	....	66.6	78.3
146	No. 12	44,580	....	9,930	8,430	16,380	552,110	16,240	51.8	53.4	59.6	48.4	49.9	55.6	....	69.4	81.7
147	No. 12	42,100	....	9,910	8,420	15,500	536,970	15,350	53.5	55.6	62.8	49.6	51.6	58.3	....	65.6	77.2
	Pennsylvania:																
65	No. 4	42,600	....	9,740	8,280	19,100	907,830	18,160	68.8	70.1	78.9	65.7	66.9	75.3	....	79.1	93.1
59	No. 5B	41,100	12,830	10,140	8,610	17,350	827,595	16,550	68.1	70.6	76.6	63.8	66.1	71.8	54.7	69.2	81.5
66	No. 6 [a]	37,500	12,860	9,750	8,280	18,410	834,695	17,760	64.2	65.6	71.2	60.3	61.6	66.9	58.5	77.3	90.9
70	Nos. 6A and 6B	40,100	....	9,690	8,240	16,740	822,430	16,450	73.1	75.3	85.8	69.0	71.1	81.0	....	72.0	84.7
88	No. 7	39,300	....	8,480	7,200	16,010	845,465	16,910	63.4	65.6	75.5	59.4	61.6	70.9	....	84.5	99.5
63	No. 8	43,050	....	9,370	7,965	20,520	971,370	19,430	87.5	89.7	96.9	81.0	83.0	89.6	....	87.9	103.4
71	No. 10	41,440	....	9,780	8,320	15,920	779,670	15,590	63.4	65.2	71.4	60.3	62.1	68.0	....	67.6	79.4
129	No. 11	42,550	....	8,520	7,240	18,780	873,120	17,460	71.5	72.9	78.8	65.9	67.2	72.6	....	86.9	102.2
143	No. 12	42,800	....	9,740	8,280	18,020	487,500	17,420	80.0	81.6	90.0	72.5	74.0	81.7	....	75.8	89.2
136	No. 13	41,580	....	9,640	8,190	17,130	684,110	16,290	64.6	66.4	76.7	59.4	60.9	70.4	....	71.6	84.3
140	No. 13	42,650	....	9,800	8,330	17,890	883,755	17,680	75.2	76.5	87.3	69.2	70.3	80.1	....	76.4	89.9
144	No. 15	43,400	....	9,565	8,130	18,560	433,320	18,050	76.0	78.0	87.2	68.5	70.4	78.7	....	80.0	94.0
148	No. 16	42,510	....	9,940	8,450	16,960	853,490	17,070	85.8	90.5	99.0	76.5	80.8	88.3	....	72.8	85.7
158	No. 17	39,800	....	9,400	7,990	16,910	847,080	16,940	64.1	67.1	77.4	60.5	63.3	73.0	....	76.5	89.9
159	No. 22	41,600	....	9,860	8,380	17,490	857,285	17,150	73.3	76.4	85.4	69.1	71.9	80.4	....	73.7	86.7
113	Rhode Island: No. 1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Tennessee:																
115	No. 1	....	....	8,430	7,165	....	....	....	....	....	....	....	....	....	....	....	....
107	No. 2	48,900	....	10,050	8,540	17,880	872,500	17,450	77.6	80.3	84.5	70.1	72.6	76.4	....	73.6	86.6
106	No. 3	47,200	....	10,030	8,520	18,500	886,940	17,740	68.5	72.0	77.5	63.1	66.3	71.4	....	75.0	88.2
111	No. 4	44,900	....	9,080	7,720	17,650	830,390	16,610	68.4	70.7	76.6	63.0	65.1	70.6	....	77.5	91.2
125	No. 5	43,100	....	9,310	7,915	19,630	911,035	18,220	70.6	72.4	79.7	94.8	66.4	73.1	....	82.9	97.6
110	No. 6	38,410	....	7,780	6,615	18,340	519,365	17,310	65.4	67.8	86.1	59.5	61.7	78.4	....	94.3	110.8
108	No. 7A	47,000	....	9,610	8,160	18,890	913,540	18,270	63.5	65.4	75.4	58.3	60.0	69.4	....	80.6	94.9
116	Nos. 8A and 8B [a]	....	....	7,215	6,130	....	....	....	....	....	....	....	....	....	....	....	....
119	Nos. 8A and 8B [a]	48,150	....	9,830	8,350	19,210	440,280	18,350	67.2	69.0	76.6	63.0	64.6	71.8	....	79.2	93.2
	Texas:																
11	No. 1	46,750	11,395	9,880	8,395	16,940	363,654	16,800	28.4	42.7	50.6	25.5	38.2	45.3	62.5	72.1	84.8
18	No. 2	41,630	11,565	10,025	8,530	16,190	309,140	16,009	34.2	51.6	57.9	30.8	46.4	52.2	58.6	67.6	79.5
93	No. 3	46,600	....	9,980	8,485	16,410	358,390	16,290	31.9	47.1	54.2	29.7	43.7	50.2	....	69.1	81.3
92	No. 4	....	....	9,650	8,200	....	....	....	....	....	....	....	....	....	....	....	....

[a] Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	British thermal units equivalent to stated horsepower per minute.				Production of gas (cubic feet).									Standard gas consumed per horsepower hour (cubic feet).		
		Gas.	Indicated.	Brake.	Electrical.	Meter per hour.	Standard gas (at 62° F. and 14.7 pounds pressure).								Indicated.	Brake.	Electrical.
							Total.	Per hour.	Per pound of fuel charged.								
									In producer.			Total used by producer plant.					
									As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.			
1	2	47	48	49	50	51	52	53	54	55	56	57	58	59	61	62	63
118	Utah: No. 1	48,250	....	10,290	8,740	17,840	844,545	16,890	59.3	62.9	66.2	55.9	59.4	62.5	....	69.6	81.9
	Virginia:																
77	No. 1	45,500	....	9,800	8,320	16,580	830,329	16,610	58.9	62.5	67.1	55.4	58.7	63.1	....	71.9	84.7
78	No. 2	....	....	9,860	8,370	....	....	....	....	....	....	....	....	....	....	....	....
75	No. 3	43,550	....	9,725	8,260	16,880	834,980	16,700	75.6	76.9	80.9	70.6	71.8	75.6	....	72.8	85.7
74	No. 4	....	....	9,800	8,325	....	....	....	....	....	....	....	....	....	....	....	....
154	No. 5A	39,950	....	9,960	8,460	14,750	448,030	14,930	56.3	58.2	71.7	51.9	53.7	66.2	....	63.5	74.7
160	No. 6	39,610	....	9,630	8,190	17,240	861,700	17,230	78.3	81.9	91.6	71.6	74.9	83.8	....	75.8	89.1
163	Jamestown No. 1	45,919	....	10,130	8,610	....	143,270	17,900	73.4	74.4	88.2	59.6	60.4	71.6	....	74.9	88.0
	Washington:																
90	No. 1A[a]	38,150	....	7,195	6,115	15,840	628,315	15,710	33.3	39.7	42.6	31.7	37.7	44.4	....	92.5	108.8
89	No. 1B	42,700	....	7,790	6,620	16,620	643,890	16,100	39.2	46.7	55.6	36.5	43.6	51.9	....	87.5	103.0
94	No. 1B	42,900	....	9,760	8,295	18,300	250,295	17,880	38.2	45.5	54.5	35.4	42.2	50.4	....	77.7	91.4
112	No. 2	43,300	....	9,760	8,300	16,770	539,745	15,430	58.1	60.5	70.7	54.8	57.1	66.8	....	67.0	78.8
	West Virginia:																
3	No. 1	43,650	11,910	9,980	8,500	18,680	435,500	18,150	63.2	64.1	68.4	56.6	57.5	61.3	64.5	77.0	90.7
4	No. 4	44,290	12,240	9,965	8,470	19,200	167,000	18,560	79.6	81.2	89.2	70.6	71.9	79.2	64.3	78.9	93.0
23	No. 7	56,090	11,530	9,930	8,440	21,290	494,990	21,850	82.5	85.1	91.4	73.0	75.3	80.9	80.3	93.3	109.7
19	No. 8	48,260	11,810	9,965	8,480	19,090	392,240	18,690	56.9	58.4	62.0	51.3	52.6	55.9	67.0	79.5	93.5
17A	No. 9	39,600	10,735	8,395	7,135	15,920	83,937	15,750	64.6	66.3	70.4	57.6	59.3	63.0	62.2	79.5	93.6
17B	No. 9	39,640	11,960	10,025	8,525	15,980	99,781	15,770	52.6	54.0	57.4	48.0	49.3	52.3	55.8	66.6	78.4
21	No. 9	46,300	11,485	9,940	8,450	17,570	415,660	17,330	69.3	70.9	76.3	60.9	62.2	67.0	63.9	73.9	86.9
161	No. 11B	39,900	....	9,700	8,240	16,390	832,635	16,650	44.1	44.3	79.0	....	....	....	....	72.7	85.7
8	No. 12	44,990	11,400	9,965	8,475	19,278	568,700	18,957	70.2	71.2	76.2	62.1	63.2	67.5	70.5	80.7	94.9
56	No. 13	45,580	12,310	10,000	8,500	20,970	982,665	19,650	100.8	103.5	107.4	94.5	97.1	100.6	67.6	83.2	98.0

54	No. 14	45,700	12,350	10,040	8,540	19,830	877,080	18,650	90.0	92.8	95.4	84.6	87.2	89.7	63.9	78.6	92.5
86	No. 16A	43,900		9,910	8,420	16,910	843,285	16,870	64.2	65.6	70.7	60.8	62.2	67.0		72.2	85.0
80	No. 18			9,880	8,390												
82	No. 20	47,100		9,800	8,320	18,470	904,035	18,080	74.4	75.8	82.1	70.3	71.6	77.6		78.3	92.1
162	No. 24	29,950		7,430	6,310	16,630	845,530	16,910	76.8	79.2	111.4					96.4	113.6
156	No. 25	40,460		9,940	8,450	14,250	706,855	14,140	54.4	56.6	61.8	51.8	53.8	58.9		60.3	70.9
164	Jamestown No. 3	42,690		10,010	8,510		2,665,720	18,500	84.1	85.3	92.3	70.9	71.8	77.7		78.3	92.1
165	Jamestown No. 4	42,975		10,140	8,620		[b] 4,121,750	17,200	80.3	81.4	86.2	69.8	70.9	75.1		71.9	84.6
166	Jamestown No. 5	44,020		9,980	8,480		3,696,030	17,330	82.4	84.0	90.0	73.0	74.5	79.7		73.6	86.6
167	Jamestown No. 7	46,000		9,780	8,320		798,550	18,150	77.4	78.7	83.4	69.7	70.8	75.0		78.6	92.4
168	Jamestown No. 7	45,560		10,000	8,500		4,259,090	17,750	81.5	82.9	87.8	72.7	74.0	78.3		75.2	88.4
	Wyoming:																
16	No. 2	37,530	11,160	10,035	8,530	15,583	447,700	14,923	37.0	40.9	53.0	32.5	35.8	46.5	56.6	63.0	74.1
62	No. 2B	42,400		9,630	8,180	18,290	849,085	17,330	41.7	45.6	59.8	39.4	43.1	56.5		76.4	89.9
69	No. 3	44,100		9,640	8,190	17,040	774,080	16,460	44.5	51.2	62.1	41.8	48.0	58.3		72.4	85.2
123	No. 4			9,750	8,290												
114	No. 5	45,150		9,700	8,245	16,910	548,650	16,140	51.8	58.4	61.0					70.5	82.9
124	No. 6			9,980	8,480												
	Miscellaneous:																
151	Coke			9,955	8,460												
50	Coke breeze	46,250		9,650	8,200	21,630	284,820	20,310	51.7	59.7	71.7					89.3	105.0
153	Refuse																

[a] Washed.

[b] 239⅔ hours between meter readings.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation.	Composition of gas (per cent of volume).							Water (cubic feet).[a]									Average pressures.					Average temperatures (° F.).		
									Producer plant (per hour).						Engine jackets.				At producer (inches of water).		Gas at meter (inches of water).				
		CO_2.	O_2.	C_2H_4.	CO.	H_2.	CH_4.	N_2.	Producer top.	Scrubber.	Tar extractor.	Total.	Per 1,000 cubic feet of standard gas.	Per horsepower per hour.	Total per hour.	Per brake-horsepower hour.	Total for plant per hour.	Barometric (inches of mercury).	Air and steam entering.	Gas leaving.	Entering.	Leaving.	Outside air.	Gas leaving producer.	Gas at meter.
1	2	64	65	66	67	68	69	70	76	77	78	75	79	80	82	83	84	87	88	89	93	94	95	97	100
	Alabama:																								
2	No. 2	8.16	0.10	0.00	16.65	7.20	5.64	62.65	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
109	No. 4	10.10	.00	.40	17.00	14.50	1.90	56.10	40	15	156	211	9.2	0.67	....	....	....	29.28	2.8	1.5	+0.6	−0.9	56	715	78
155	No. 6	9.60	.00	.10	19.50	14.90	1.70	54.20	64	56	31	151	8.9	.60	....	....	....	29.39	3.6	1.2	+1.1	− .9	30	837	58
	Argentina:																								
141	Argentina (special)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
169	Jamestown No. 8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Arkansas:																								
96	No. 7A	14.80	.00	.00	12.10	16.10	1.60	55.40	32	57	....	....	....	....	....	....	....	29.94	....	2.7	+1.2	− .5	....	648	68
95	No. 8	11.30	.20	.20	15.90	14.70	1.00	56.70	26	26	....	....	....	....	....	....	....	29.29	....	3.2	+ .6	−2.0	....	599	62
91	No. 10	13.50	.00	.00	14.00	9.20	2.40	60.90	35	52	....	....	....	....	....	....	....	29.85	....	3.0	+1.4	−1.4	....	459	47
44	Brazil: No. 1	11.45	.10	.00	15.86	10.76	2.90	58.93	62	118	159	339	20.9	1.36	....	....	....	29.56	....	3.4	+1.3	− .0	....	972	90
	California:																								
32	No. 1	10.00	.08	.00	19.24	11.40	3.91	55.37	....	....	90	....	....	....	....	....	....	29.33	....	2.4	+1.2	− .5	....	759	86
33	No. 1 [b]	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
34	No. 1 [b]	9.66	.01	.00	18.07	7.85	2.97	61.44	....	....	28	....	....	....	....	....	....	29.38	....	2.8	+1.1	− .9	....	759	86
15	Colorado: No. 1	10.11	.55	.00	17.38	11.05	5.00	55.91	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
117	Florida: No. 1	12.40	.00	.40	21.00	18.50	2.20	45.50	25	56	....	....	....	....	....	....	....	29.25	1.9	1.3	+1.0	− .1	74	355	88
	Illinois:																								
6	No. 3	10.53	.15	.00	15.31	8.35	4.46	61.20	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
9	No. 4	9.72	.12	.00	15.12	9.98	6.00	59.06	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
35	No. 6B	7.82	.12	.00	20.90	9.01	3.72	58.43	....	....	71	....	....	....	....	....	....	29.39	....	2.5	+1.2	− .4	....	810	85
26	No. 7A	11.87	.00	.00	10.67	7.88	3.83	65.75	100		48	148	8.6	.59	....	....	....	29.36	....	4.4	+1.3	− .3	....	878	71
27	No. 7B	10.93	.06	.00	12.56	9.41	4.92	62.12	97		73	170	8.6	.68	....	....	....	29.55	....	5.4	+1.2	− .9	....	1,086	74
38	No. 7C	11.21	.02	.00	14.48	7.67	3.16	63.46	....	....	32	....	....	....	....	....	....	29.50	....	3.3	+1.2	− .8	....	1,216	85
29	No. 8	8.04	.06	.03	19.83	10.32	3.09	58.63	....	....	113	....	....	....	....	....	....	29.42	....	2.7	+1.2	− .6	....	834	74

28	No. 9B	8.87	.08	.02	16.01	9.40	5.08	60.54	....	....	103	....	....	....	....	....	....	29.48	....	2.9	+1.2	− .7	....	958	75
31	No. 10	8.95	.04	.00	18.52	11.47	3.14	57.88	....	....	83	....	....	....	....	....	....	29.54	....	1.2	+1.2	− .7	....	981	78
30	No. 11A	6.33	.03	.00	19.71	9.68	6.20	58.05	....	....	128	....	....	....	....	....	....	29.53	....	1.8	+1.3	− .3	....	840	78
36	No. 11C[c]	12.16	.07	.00	12.64	9.54	3.46	62.13	....	....	63	....	....	....	....	....	....	29.47	....	3.9	+1.1	−1.2	....	761	85
42	No. 11D[c]	10.19	.00	.00	18.32	13.23	2.60	55.66	57	99	116	272	14.3	1.08	....	....	....	29.34	....	3.4	+1.3	− .6	....	944	83
48	No. 11D[c]	7.39	.00	.00	22.85	13.35	2.36	54.05	41	77	108	226	14.7	.91	....	....	....	29.51	....	2.2	+1.3	− .3	....	732	87
41	No. 13	8.06	.00	.00	20.98	11.59	3.11	56.26	35	98	83	216	11.8	.86	....	....	....	29.35	....	2.6	+1.3	− .5	....	890	87
37	No. 14	8.23	.01	.00	20.97	10.66	3.21	56.92	....	....	54	....			....	....	....	29.49	....	2.4	+1.3	− .2	....	923	83
39	No. 15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
40	No. 15	11.13	.00	.00	16.14	11.22	3.25	58.26	42	88	107	237	12.3	.95	....	....	....	29.26	....	1.9	+1.2	− .7	....	956	85
43	No. 16	8.00	.00	.00	21.60	12.90	2.70	54.80	55	114	81	250	13.9	1.00	....	....	....	29.59	....	3.6	+1.3	− .4	....	756	88
45	No. 18	11.40	.00	.00	17.20	12.80	3.20	55.40	57	128	102	287	16.1	1.15	....	....	....	29.46	....	6.4	+1.3	− .6	....	973	86
55	No. 19B	7.36	.00	.00	23.89	15.69	2.10	50.96	50	47	44	141	8.0	.56	....	....	....	29.55	....	2.2	+1.3	− .1	....	594	89
128	No. 19C	11.60	.00	.30	16.80	16.50	1.90	52.90	39	....	....	....	....	....	....	....	....	29.41	5.7	2.0	+1.3	− .3	78	662	90
105	No. 21	9.20	.00	.40	20.90	15.60	1.90	52.00	39	33	67	139	9.2	.60	....	....	....	29.56	....	2.2	+1.0	− .4	33	644	59
102	No. 22A	9.40	.00	.70	20.20	13.70	2.00	51.00	32	9	163	204	11.8	.81	....	....	....	29.83	3.8	2.5	+1.3	− .3	25	986	63
98	No. 23A	8.40	.00	.50	20.90	12.90	1.60	55.70	31	61	....	....	....	....	....	....	....	29.82	....	3.4	+1.2	− .2	....	757	71
100	No. 23B	10.90	.00	.70	17.20	13.80	2.10	55.30	33	44	41	118	6.7	.47	....	....	....	29.72	6.1	5.2	+1.3	− .5	....	909	65
103	No. 24B	8.40	.10	.50	22.60	13.80	2.10	52.50	34	39	74	147	9.3	.59	....	....	....	29.31	2.9	2.0	+1.4	− .2	50	664	78
104	No. 25	8.30	.00	.50	22.50	13.60	2.20	52.90	29	39	118	186	12.7	.74	....	....	....	29.66	2.7	1.8	+1.6	+ .2	24	717	65
126	No. 26	10.50	.00	.40	19.40	15.50	1.70	52.50	39	60	107	206	11.7	.82	....	....	....	29.41	3.1	2.1	+ .6	− .9	84	694	93
127	No. 27	12.40	.00	.40	15.00	12.90	1.60	57.70	46	62	70	178	10.5	.71	....	....	....	29.71	2.0	1.5	+ .6	− .8	78	745	90
139	No. 29B	11.40	.00	.50	17.30	14.00	2.00	54.80	45	74	80	199	....	.80	....	....	....	29.26	2.1	1.4	....	....	62	456	....
157	No. 30[c]	9.30	.00	.60	19.60	13.80	2.00	54.70	59	63	....	....	....	....	....	....	....	29.71	1.6	.6	+ .5	− .6	39	727	59
	Indiana:																								
14	No. 1	9.89	.25	.00	14.10	9.56	6.08	60.12	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
13A	No. 2	10.85	.16	.00	13.45	11.29	5.52	58.73	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
13B	No. 2	11.80	.07	.00	11.46	10.60	6.10	59.97	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
53	No. 3[c]	10.70	.00	.00	18.10	10.60	2.70	57.90	47	75	119	241	13.1	.96	....	....	....	29.41	....	5.5	+1.3	− .5	....	894	89
46	No. 5	12.02	.00	.00	15.15	11.75	2.95	58.13	60	131	211	402	22.3	1.61	....	....	....	29.65	....	7.9	+1.2	− .8	....	899	84
47	No. 5	10.09	.00	.00	18.76	11.46	2.85	56.84	60	77	160	297	17.5	1.19	....	....	....	29.41	....	3.2	+1.3	− .6	....	832	85
49	No. 6	9.80	.00	.00	18.10	12.80	2.40	56.90	48	69	98	215	....	.86	....	....	....	29.43	....	3.0	....	....	....	806	....
51	No. 7A	8.16	.00	.00	22.15	11.90	3.15	54.64	46	55	102	203	12.6	.81	....	....	....	29.48	....	2.4	+ .9	− .4	....	712	88
57	No. 8	9.50	.00	.00	20.10	11.30	2.80	56.30	46	49	91	186	10.6	.74	375	1.59	561	29.41	....	2.7	+1.3	− .1	....	765	90
52	No. 9A	10.55	.00	.00	18.00	11.52	2.81	57.12	45	83	81	209	11.6	.84	....	....	....	29.31	....	3.3	+1.3	− .3	....	682	87
61	No. 11	10.60	.00	.00	18.30	13.90	3.10	54.10	39	68	99	206	11.9	.83	286	1.21	492	29.55	....	3.3	+1.3	− .4	....	680	84
99	No. 12	9.60	.00	.70	19.20	12.80	1.80	55.90	38	55	....	....	....	....	....	....	....	30.01	....	2.9	+1.3	− .4	....	779	59
132	No. 13	12.50	.00	.40	14.90	12.80	1.90	57.50	45	....	....	....	....	....	....	....	....	29.39	2.5	1.9	+ .7	− .8	73	774	90
138	No. 13	10.90	.00	.40	18.00	15.20	1.90	53.60	33	26	87	146	....	.58	....	....	....	29.49	1.4	1.0	....	....	61	....	....
131	No. 14	9.80	.00	.50	20.40	14.40	2.20	52.70	33	....	....	....	....	....	....	....	....	29.47	2.1	1.4	+ .8	− .5	69	....	86
134	No. 15	11.20	.00	.40	17.20	15.20	2.20	53.80	54	....	....	....	....	....	....	....	....	29.44	2.7	1.9	+ .6	− .9	70	638	86
137	No. 15	10.60	.00	.40	18.30	14.90	2.00	53.80	41	74	147	262	16.4	1.10	....	....	....	29.52	1.8	.9	+ .7	− .8	54	635	71
130	No. 16	11.40	.00	.50	16.80	13.30	1.70	56.30	42	....	....	....	....	....	....	....	....	29.32	2.5	2.0	+ .9	− .7	78	722	91
133	No. 18B	10.00	.00	.30	19.40	16.00	2.10	52.20	43	....	....	....	....	....	....	....	....	29.38	2.6	2.1	+ .7	− .6	68	638	86
135	No. 18B	10.80	.00	.30	18.60	16.90	2.10	51.30	41	....	....	....	....	....	....	....	....	29.42	2.8	2.6	+1.1	− .3	67	539	82
	Indian Territory:																								
1	No. 1	8.25	.11	.00	19.39	7.69	4.92	59.64	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
20	No. 4	7.29	.24	.00	17.64	10.43	6.30	58.10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
22	Iowa: No. 2	10.06	.17	.00	12.57	9.53	7.67	60.00	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

[a] Water supply could not be conveniently regulated, owing to varying pressure in the mains; no attempt was made to hold to the minimum.

[b] Mixed with 50 per cent "front-end" cinders from locomotives in test 33, and with 33⅓ per cent of the same cinders in test 34.

[c] Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation.	Composition of gas (per cent of volume).							Water (cubic feet).									Average pressures.					Average temperatures (° F.).		
									Producer plant (per hour).						Engine jackets.				At producer (inches of water).		Gas at meter (inches of water).				
		CO₂.	O₂.	C₂H₄.	CO.	H₂.	CH₄.	N₂.	Producer top.	Scrubber.	Tar extractor.	Total.	Per 1,000 cubic feet of standard gas.	Per horsepower per hour.	Total per hour.	Per brake-horsepower hour.	Total for plant per hour.	Barometric (inches of mercury).	Air and steam entering.	Gas leaving.	Entering.	Leaving.	Outside air.	Gas leaving producer.	Gas at meter.
1	**2**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**76**	**77**	**78**	**75**	**79**	**80**	**82**	**83**	**84**	**87**	**88**	**89**	**93**	**94**	**95**	**97**	**100**
	Kansas:																								
24	No. 5	10.27	0.13	0.00	12.40	9.05	7.42	60.73	....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	......	....
25	No. 5	9.06	.26	.01	15.53	10.83	3.08	61.23	....	....	138	.....	.....	.....	.....	.....	.....	29.47	.....	5.1	+1.4	−0.5	....	867	77
101	No. 6	8.20	.00	.60	21.00	12.70	2.10	55.40	43	41	96	180	10.2	0.72	.....	.....	.....	29.66	2.4	1.9	+1.3	− .5	40	661	69
	Kentucky:																								
79	No. 1B	9.20	.00	.00	20.30	14.20	3.50	52.80	36	86	.....	.....	.....	.....	.....	.....	.....	29.44	.....	1.5	+1.3	− .4	....	624	63
12	No. 3	10.87	.29	.00	12.45	10.92	6.52	58.95	....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	......	....
81	No. 5	8.80	.00	.00	21.00	14.90	3.40	51.90	34	58	.....	.....	.....	.....	.....	.....	.....	29.47	.....	1.4	+1.4	− .1	....	......	61
85	No. 6	7.70	.00	.00	23.60	16.60	2.90	49.20	25	60	.....	.....	.....	.....	.....	.....	.....	29.79	.....	1.3	+1.4	− .0	....	496	54
84	No. 7	9.60	.00	.00	19.20	13.10	3.10	55.00	33	46	.....	.....	.....	.....	.....	.....	.....	30.04	.....	1.6	+1.4	− .3	....	594	52
97	Massachusetts: No. 1	10.50	.00	.00	22.50	13.90	2.10	51.00	18	56	.....	....	.....	.....	.....	.....	.....	29.47	.....	2.2	+1.2	− .3	....	319	78
	Missouri:																								
7A	No. 2	11.27	.33	.00	11.80	5.77	3.20	67.63	....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	......	....
7B	No. 2	12.07	.20	.00	10.53	7.63	6.33	63.24	....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	......	....
	Montana:																								
5A	No. 1	9.04	.36	.00	18.67	8.00	4.84	59.09	....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	......	....
5B	No. 1	13.00	.05	.00	9.85	1.37	3.39	72.34	....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	......	....
149	No. 2	13.20	.20	.60	14.20	16.00	2.90	52.90	54	59	58	171	9.6	.68	.....	.....	.....	29.88	.....	.9	+ .8	− .7	35	761	59
150	No. 3	8.00	.00	.40	23.20	15.90	3.30	49.20	38	54	72	164	10.4	.66	.....	.....	.....	29.42	2.2	1.3	+ .8	− .7	45	......	62
	New Mexico:																								
121	No. 3A	9.20	.00	.40	20.50	14.50	2.00	53.40	43	47	.....	.....	.....	.....	.....	.....	.....	29.40	2.5	1.7	+ .9	− .6	77	722	86
122	4A	10.60	.00	.60	17.00	12.60	2.00	57.20	38	57	.....	.....	.....	.....	.....	.....	.....	29.40	2.5	1.6	+ .5	−1.1	67	810	83
120	No. 5	8.60	.00	.50	21.40	14.60	2.20	52.70	39	50	.....	.....	.....	.....	.....	.....	.....	29.21	2.7	1.7	+ .9	− .7	77	670	86
	North Dakota:																								
68	No. 1B	8.20	.00	.00	25.20	15.30	2.60	48.70	18	76	242	336	21.8	1.35	304	1.30	640	29.52	.....	2.1	+1.4	− .0	....	......	73
10	No. 2	8.69	.23	.00	20.90	14.33	4.85	51.00	....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	......	....

72	No. 2B	9.30	.00	.00	22.90	15.60	2.70	49.50	21	35	124	180	......	.72	.....	......	.....	29.53	.....	2.5	+1.3	− .0	....	....	68
152	No. 2B	9.20	.50	.20	21.80	13.30	1.70	53.30	40	53	53	146	8.4	.58	.....	......	.....	29.91	2.0	1.3	+ .8	− .8	38	381	62
67	No. 3	9.00	.00	.00	23.20	15.50	2.70	49.60	43	84	123	250	15.8	1.00	321	1.40	571	29.58	.....	2.3	+1.3	+ .1	....	....	80
	Ohio:																								
64	No. 3[a]	8.20	.00	.00	22.70	15.10	2.50	51.50	43	34	103	180	10.5	.72	.....	......	.....	29.53	.....	2.4	+1.4	− .2	....	575	80
60	No. 4	9.60	.00	.00	20.00	13.00	2.70	54.70	41	76	77	194	10.9	.78	299	1.26	493	29.52	.....	2.4	+1.3	− .0	....	712	81
58	No. 5	8.90	.00	.00	20.70	12.70	3.00	54.70	46	47	127	220	12.9	.88	341	1.43	561	29.65	.....	3.5	+1.3	+ .6	....	797	84
76	No. 6	10.40	.00	.00	19.10	14.10	3.60	52.80	43	89	.....	.....	......	......	.....	......	.....	29.47	.....	1.5	+1.3	− .2	....	562	67
87	No. 7	9.50	.00	.00	20.40	12.30	3.10	54.70	32	42	.....	.....	......	......	.....	......	.....	29.73	.....	2.5	+1.3	− .5	....	690	50
83	No. 8	6.50	.00	.00	24.50	12.30	3.10	53.60	26	22	.....	.....	......	......	.....	......	.....	29.78	.....	1.4	+1.4	+ .1	....	....	55
73	No. 9A	14.50	.00	.00	13.80	18.10	3.00	50.60	35	72	125	232	......	.93	.....	......	.....	29.66	.....	2.9	+1.3	− .1	....	688	66
142	No. 10	9.40	.00	.50	20.70	14.20	2.60	52.60	29	38	50	117	7.3	.46	.....	......	.....	29.54	1.6	.8	+ .8	− .4	52	....	69
145	No. 11	9.00	.00	.50	20.20	15.30	2.70	52.30	30	57	92	179	11.5	.72	.....	......	.....	29.25	1.4	1.0	+1.1	− .1	35	756	59
146	No. 12	9.40	.00	.40	19.80	15.70	2.90	51.80	25	54	95	174	10.7	.70	.....	......	.....	29.06	1.9	1.7	+1.1	− .1	45	782	62
147	No. 12	9.30	.00	.50	19.90	15.20	2.50	52.60	43	66	63	172	......	.69	.....	......	.....	29.33	2.0	1.4	+1.5	+ .4	37	792	58
	Pennsylvania:																								
65	No. 4	8.70	.00	.00	20.70	12.50	2.50	55.60	59	80	63	202	11.1	.81	312	1.36	514	29.41	.....	2.4	+1.4	− .3	....	782	81
59	No. 5B	9.60	.00	.00	19.40	12.70	3.30	55.00	42	50	158	250	15.1	1.00	285	1.19	535	29.63	.....	2.7	+1.3	− .0	....	642	83
66	No. 6[a]	10.00	.00	.00	18.50	12.10	2.40	57.00	57	87	192	336	18.9	1.34	276	1.20	612	29.58	.....	3.5	+1.4	− .2	....	486	76
70	Nos. 6A and 6B	9.60	.00	.00	19.20	11.50	3.00	56.70	52	70	116	238	14.5	.95	.....	......	.....	29.66	.....	1.9	+1.3	− .4	....	557	70
88	No. 7	10.20	.00	.00	17.50	11.30	2.50	58.50	49	36	.....	.....	......	......	.....	......	.....	29.48	.....	2.0	+1.0	− .8	....	746	54
63	No. 8	9.90	.00	.00	18.70	14.10	2.20	55.10	52	76	101	229	11.8	.91	310	1.40	539	29.54	.....	2.9	+1.2	− .7	....	849	84
71	No. 10	9.20	.00	.00	20.40	13.80	3.40	53.20	46	60	95	201	12.9	.80	.....	......	.....	29.64	.....	1.8	+1.3	− .4	....	596	69
129	No. 11	10.40	.00	.20	18.50	16.30	2.00	52.60	34	....	.....	.....	......	......	.....	......	.....	29.33	3.6	1.8	+1.1	− .5	80	664	91
143	No. 12	10.80	.00	.50	16.60	14.90	2.40	54.80	36	40	62	138	7.9	.55	.....	......	.....	29.45	1.8	1.2	+ .8	− .7	50	782	71
136	No. 13	11.00	.00	.50	17.20	14.90	2.40	54.00	51	60	.....	.....	......	......	.....	......	.....	29.28	1.9	1.4	+ .8	− .6	62	761	77
140	No. 13	11.10	.00	.60	16.50	12.60	2.10	57.10	42	69	52	163	9.2	.65	.....	......	.....	29.38	1.9	1.2	+ .7	− .7	40	653	62
144	No. 15	10.70	.00	.30	17.20	15.80	2.20	53.80	40	26	57	123	6.8	.49	.....	......	.....	29.48	2.2	1.5	+ .8	− .8	43	852	68
148	No. 16	10.10	.00	.40	18.20	15.80	2.30	53.20	35	53	92	180	10.6	.72	.....	......	.....	29.88	2.5	1.7	+1.3	− .5	34	864	59
158	No. 17	10.00	.10	.40	17.50	13.70	2.20	56.10	55	60	39	154	9.1	.62	.....	......	.....	29.86	1.8	1.1	+ .5	− .5	31	788	55
159	No. 22	10.10	.00	.40	17.60	13.30	2.20	56.40	58	57	46	161	9.4	.65	.....	......	.....	29.25	2.5	1.5	+ .5	− .5	48	768	60
113	Rhode Island: No. 1	......	......	......	......	......	......	......	....	....	.....	.....	......	......	.....	......	.....	......	.....	.....	......	......	....	....	....
	Tennessee:																								
115	No. 1	10.00	.00	.40	19.60	15.30	2.10	52.60	43	75	.....	.....	......	.47	.....	......	.....	29.54	2.6	1.6	......	......	75	626	....
107	No. 2	10.90	.00	.50	18.80	18.60	2.20	49.00	36	34	104	174	10.0	.70	.....	......	.....	29.71	3.1	1.6	+1.1	− .1	52	507	72
106	No. 3	9.80	.00	.40	20.20	16.50	2.40	50.70	35	17	203	255	14.4	1.00	.....	......	.....	29.30	4.3	2.0	+1.3	− .0	53	....	74
111	No. 4	10.40	.00	.50	19.00	16.70	2.40	51.00	31	28	119	178	10.7	.71	.....	......	.....	29.33	3.2	1.5	+ .9	− .2	69	650	84
125	No. 5	11.30	.00	.50	17.00	15.30	1.70	54.20	41	64	111	216	11.9	.87	.....	......	.....	29.46	3.5	1.8	+ .5	−1.1	79	728	88
110	No. 6	12.30	.00	.40	15.00	14.00	1.90	56.40	43	45	157	245	14.2	.98	.....	......	.....	29.21	1.8	1.4	+ .6	− .8	72	682	84
108	No. 7A	11.20	.00	.50	17.40	15.30	2.30	53.30	40	26	149	215	11.8	.86	.....	......	.....	29.49	2.9	2.2	+ .8	− .6	63	648	78
116	Nos. 8A and 8B[a]	9.90	.00	.40	19.70	14.30	1.90	53.80	36	66	.....	.....	......	.41	.....	......	.....	29.48	2.4	1.7	......	......	77	652	....
119	Nos. 8A and 8B[a]	9.70	.00	.50	19.10	15.10	2.10	53.50	57	73	190	320	17.4	1.28	.....	......	.....	29.37	3.9	2.0	+1.3	− .0	65	628	77
	Texas:																								
11	No. 1	11.10	.22	.00	14.43	10.54	7.48	56.23	....	....	.....	.....	......	......	.....	......	.....	......	.....	.....	......	......	....	....	....
18	No. 2	9.60	.20	.00	18.22	9.63	4.81	57.54	....	....	.....	.....	......	......	.....	......	.....	......	.....	.....	......	......	....	....	....
93	No. 3	10.30	.70	.70	19.80	14.80	2.40	51.30	12	32	.....	.....	......	......	.....	......	.....	29.38	.....	2.2	+ .9	− .8	....	....	56
92	No. 4	10.30	.00	.00	20.00	15.40	2.50	51.80	20	47	.....	.....	......	......	.....	......	.....	29.72	.....	2.5	+1.1	− .8	....	....	58

[a] Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation.	Composition of gas (per cent of volume).							Water (cubic feet).									Average pressure.						Average temperatures (° F.).		
									Producer plant (per hour).						Engine jackets.				At producer (inches of water).		Gas at meter (inches of water).				
		CO_2.	O_2.	C_2H_4.	CO.	H_2.	CH_4.	N_2.	Producer top.	Scrubber.	Tar extractor.	Total.	Per 1,000 cubic feet of standard gas.	Per horsepower per hour.	Total per hour.	Per brake-horsepower hour.	Total for plant per hour.	Barometric (inches of mercury).	Air and steam entering.	Gas leaving.	Entering.	Leaving.	Outside air.	Gas leaving producer.	Gas at meter.
1	**2**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**76**	**77**	**78**	**75**	**79**	**80**	**82**	**83**	**84**	**87**	**88**	**89**	**93**	**94**	**95**	**97**	**100**
118	Utah: No. 1	8.50	0.00	0.50	22.20	15.70	2.60	50.50	32	52	122	206	12.2	0.82	....	....	....	29.37	1.4	1.1	+0.8	−0.3	69	572	82
	Virginia:																								
77	No. 1	10.00	.00	.00	19.70	14.90	3.60	51.80	40	57	....	....	....	....	....	....	....	29.87	....	1.7	+1.3	− .4	....	573	61
78	No. 2	8.20	.00	.00	22.30	13.00	3.50	53.00	40	45	....	....	....	....	....	....	....	29.41	....	1.4	+1.3	− .2	....	582	62
75	No. 3	9.70	.00	.00	19.30	13.80	3.10	54.10	45	86	....	....	....	....	....	....	....	29.50	....	1.9	+1.3	− .4	....	662	61
74	No. 4	7.50	.00	.00	23.50	13.80	3.30	51.90	37	89	....	....	....	....	....	....	....	29.69	....	1.6	+1.4	− .1	....	583	61
154	No. 5A	10.20	.00	.10	19.10	20.50	1.90	48.20	31	61	48	140	9.4	.56	....	....	....	29.96	5.4	1.2	+1.2	−1.5	27	332	55
160	No. 6	10.50	.00	.30	17.40	14.30	2.00	55.50	77	41	....	....	....	....	....	....	....	29.58	2.3	1.2	+ .7	− .6	31	803	56
163	Jamestown No. 1	9.7	.00	.00	19.70	14.50	2.30	53.80	....	....	....	....	....	....	298	1.25	....	30.13	1.6	1.0	+1.1	− .5	89	547	97
	Washington:																								
90	No. 1A[a]	11.30	.00	.00	15.40	10.50	3.60	59.20	39	50	....	....	....	....	....	....	....	29.34	....	1.8	+1.3	− .4	....	410	57
89	No. 1B	13.40	.00	.00	14.50	16.70	3.80	51.60	32	36	....	....	....	....	....	....	....	28.98	....	2.3	+1.3	− .7	....	490	58
94	No. 1B	12.60	.20	.70	13.90	12.80	2.40	57.40	17	30	....	....	....	....	....	....	....	29.24	....	2.8	+ .7	−1.4	....	....	62
112	No. 2	7.90	.00	.40	22.20	15.40	2.60	51.50	32	53	114	199	12.8	.79	....	....	....	29.17	1.3	1.0	+ .8	− .3	67	614	84
	West Virginia:																								
3	No. 1	10.50	.10	.00	14.34	2.81	5.56	66.69	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
4	No. 4	10.16	.24	.00	15.82	11.16	3.74	58.88	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
23	No. 7	9.62	.08	.00	12.75	10.31	6.76	60.48	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
19	No. 8	10.33	.22	.00	11.93	9.45	6.40	61.67	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
17A	No. 9	10.47	.33	.00	11.20	10.90	6.20	60.90	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
17B	No. 9	10.40	.20	.00	13.70	9.45	6.60	59.55	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
21	No. 9	8.90	.33	.00	14.77	9.52	6.65	59.83	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
161	No. 11B	9.70	.00	.00	19.50	16.60	1.60	52.60	74	33	....	....	....	....	....	....	....	29.48	2.1	1.2	+ .7	− .8	19	782	50
8	No. 12	10.34	.12	.00	14.21	12.98	4.61	57.74	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
56	No. 13	9.80	.00	.00	18.40	13.70	2.30	55.80	45	57	105	207	10.5	.83	301	1.27	508	29.53	...	2.8	+1.2	− .6	....	750	91
54	No. 14	8.60	.00	.00	20.72	13.31	2.32	55.05	60	31	71	162	8.7	.65	....	....	....	29.50	....	2.7	+1.3	− .5	....	745	88

86	No. 16A	8.40	.00	.00	21.20	14.00	2.50	53.90	33	28	.....	.....	.....	.....	.....	.....	.....	29.54	.....	1.9	+1.3	− .5	....	624	54
80	No. 18	8.60	.00	.00	21.50	12.90	3.70	53.30	36	18	.....	.....	.....	.....	.....	.....	.....	29.92	.....	1.7	.....	.....	....	552	....
82	No. 20	8.30	.00	.00	21.00	13.10	2.60	55.00	35	58	.....	.....	.....	.....	.....	.....	.....	29.33	.....	1.6	+1.3	− .3	....	.....	64
162	No. 24	12.40	.00	.00	14.00	13.80	1.20	58.60	75	72	.....	.....	.....	.....	.....	.....	.....	29.71	2.7	1.7	+ .5	−1.0	25	872	49
156	No. 25	7.90	.00	.40	23.40	17.10	2.10	49.10	47	41	.....	.....	.....	.....	.....	.....	.....	29.37	1.6	.8	+ .6	− .1	38	531	57
164	Jamestown No. 3	10.50	.00	.00	18.40	16.40	2.00	52.70	23	43	21	87	4.7	.....	246	1.04	333	30.21	2.5	1.4	+1.1	− .6	69	.....	84
165	Jamestown No. 4	9.20	.00	.00	20.00	16.20	2.20	52.40	23	42	38	103	6.0	.....	248	1.04	351	30.12	2.4	1.7	+1.2	− .6	69	.....	76
166	Jamestown No. 5	7.90	.00	.00	22.20	14.10	2.40	53.40	26	32	35	93	5.4	.....	243	1.04	336	30.34	1.5	1.1	+1.2	− .7	64	858	74
167	Jamestown No. 7	7.30	.00	.00	22.80	14.30	2.10	53.50	28	72	50	150	8.2	.....	268	1.16	418	30.28	1.3	.9	+1.2	− .7	62	830	65
168	Jamestown No. 7	7.20	.00	.00	23.10	15.20	1.90	52.60	26	34	33	93	5.3	.....	277	1.18	370	30.09	1.8	1.4	+1.2	− .6	64	815	70
	Wyoming:																								
16	No. 2	10.21	.59	.00	15.46	10.79	5.52	57.43	....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	.....	....
62	No. 2B	10.80	.00	.00	18.20	10.70	3.30	57.00	42	56	88	186	10.7	.74	301	1.33	487	29.49	.....	2.5	+1.4	− .1	....	792	84
69	No. 3	11.10	.00	.00	19.80	13.30	3.50	52.30	39	63	219	321	19.5	1.28	.....	.....	.....	29.46	.....	2.4	+1.3	− .1	....	532	72
123	No. 4	12.20	.00	.40	16.40	15.10	2.70	53.20	32	62	191	285	18.9	1.14	.....	.....	.....	29.34	4.3	1.7	+ .7	− .6	66	673	80
114	No. 5	10.10	.00	.40	20.40	18.20	2.60	48.30	25	54	177	256	15.9	1.02	.....	.....	.....	29.57	3.2	1.4	+ .7	− .6	67	.....	79
124	No. 6	12.10	.00	.40	18.70	19.30	3.00	46.50	29	72	.....	.....	.....	.....	.....	.....	.....	29.09	7.2	1.5	.....	.....	70	264	....
	Miscellaneous:																								
151	Coke	9.20	.00	.10	21.90	11.10	.20	57.50	52	66	.....	.....	.....	.....	.....	.....	.....	29.64	3.4	2.4	.....	.....	32	883	....
50	Coke breeze	8.74	.00	.00	23.28	12.81	.37	54.80	51	68	112	231	24.4	.93	.....	.....	.....	29.51	.....	4.2	.....	.....	....	581	....
153	Refuse	.....	.....	.....	.....	.....	.....	.....	....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	.....	....

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a Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Gas horsepower.	Revolutions per minute of gas engine.	Explosions per minute per cylinder.	Indicated horsepower.													Brake horsepower.[a]		Electrical horsepower.	
					Indicator card pressures (pounds per square inch).									Cylinder 1.	Cylinder 2.	Cylinder 3.	Total.	Developed at engine.	Commercially available.	Developed at switchboard.	Commercially available.
					Maximum.			At release.			Mean effective pressure.										
					Cylinder 1.	Cylinder 2.	Cylinder 3.	Cylinder 1.	Cylinder 2.	Cylinder 3.	Cylinder 1.	Cylinder 2.	Cylinder 3.								
1	**2**	**103**	**104**	**105**	**106**	**107**	**108**	**109**	**110**	**111**	**112**	**113**	**114**	**115**	**116**	**117**	**118**	**119**	**120**	**121**	**122**
	Alabama:																				
2	No. 2	987	201.1	100.5	282.9	286.5	279.0	30.3	31.0	28.8	64.5	63.2	57.4	102.1	100.0	91.3	293.4	235.5	226.6	200.6	192.6
109	No. 4	1,097	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	229.5	216.0	195.0	183.6
155	No. 6	955	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	233.8	226.5	198.6	192.5
	Argentina:																				
141	Argentina (special)				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
169	Jamestown, No. 8	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
	Arkansas:																				
96	No 7A	933	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	161.5	147.6	137.3	125.5
95	No. 8	1,040	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	208.4	197.7	177.2	168.1
91	No. 10	593	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	151.5	139.6	128.7	118.6
44	Brazil: No. 1	836	205.4	102.7	221.7	188.5	215.2	18.7	22.2	20.0	44.7	51.0	48.0	72.4	82.7	77.9	233.0	166.9	150.9	141.8	128.2
	California:																				
32	No. 1	1,132	202.0	101.0	......	......	......	......	......	......	......	......	......	......	......	......	......	244.0	229.7	207.4	195.2
33	No 1[b]	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
34	No 1[b]	1,019	201.8	100.9	......	......	......	......	......	......	......	......	......	......	......	......	......	242.7	232.4	206.2	197.6
15	Colorado: No. 1	898	202.8	101.4	260.7	270.3	258.0	30.0	29.3	27.4	58.4	58.5	52.5	92.9	93.3	84.2	270.4	235.4	219.3	200.2	186.4
117	Florida: No. 1	1,217	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	241.2	231.0	205.0	196.3
	Illinois:																				
6	No. 3	1,059	200.9	100.4	266.1	286.8	242.4	30.3	30.0	27.7	61.2	57.7	50.5	69.9	96.3	80.0	268.2	235.0	226.5	199.6	192.5
9	No. 4	1,067	202.9	101.5	262.5	265.0	264.1	26.0	29.5	24.5	53.6	56.1	67.0	85.5	89.7	81.8	257.0	233.0	223.0	189.4	189.1
35	No. 6B	1,079	200.6	100.3	271.5	286.6	273.0	27.8	30.8	28.2	63.9	65.8	59.2	102.1	105.2	94.6	301.9	243.0	229.8	206.7	195.3
26	No. 7A	744	206.5	103.3	......	......	......	......	......	......	......	......	......	......	......	......	......	163.0	153.3	138.6	130.3
27	No. 7B	1,066	203.7	101.9	......	......	......	......	......	......	......	......	......	......	......	......	......	240.2	229.8	204.1	195.2
38	No. 7C	934	201.3	100.7	244.7	278.7	286.0	25.7	28.8	25.5	60.3	62.8	53.3	95.4	99.4	89.6	284.4	205.8	191.8	174.8	163.1
29	No. 8	1,075	204.2	102.1	......	......	......	......	......	......	......	......	......	......	......	......	......	244.8	233.0	208.0	197.9
28	No. 9B	1,070	202.4	101.2	......	......	......	......	......	......	......	......	......	......	......	......	......	244.8	233.0	208.0	198.1
31	No. 10	1,070	202.5	101.3	......	......	......	......	......	......	......	......	......	......	......	......	......	244.2	229.7	207.5	195.2

30	No. 11A	1,152	205.1	102.6														247.0	230.8	210.0	196.2
36	No. 11 C[c]	921	201.1	100.6	257.1	259.8	251.6	28.2	28.5	28.2	55.3	57.3	55.3	87.8	90.8	87.7	266.3	204.6	191.0	173.9	162.4
42	No. 11D[c]	1,023	203.6	101.8	271.8	268.5	286.0	28.2	30.5	21.6	61.4	63.3	58.5	98.7	101.8	93.9	294.4	236.5	221.5	201.0	188.3
48	No. 11D[c]				249.0	265.0	269.0	26.0	30.0	21.0	61.0	64.0	60.0	98.5	102.6	94.0	295.1	238.3	224.2	202.5	190.5
41	No. 13	996	202.8	101.4	264.2	265.8	290.5	28.6	28.6	29.1	64.7	70.8	65.3	103.3	113.0	103.7	320.0	245.5	232.5	208.7	197.6
37	No. 14	1,016	202.3	101.2	249.1	259.6	237.6	29.3	29.7	27.3	63.3	62.4	57.3	100.6	99.1	91.0	290.7	234.1	220.9	199.0	187.6
39	No. 15																				
40	No. 15	1,074	200.2	100.1	258.9	261.7	274.3	30.8	32.3	28.1	60.8	65.1	59.3	95.6	102.5	93.3	291.4	236.0	221.7	200.5	188.4
43	No. 16	1,059	203.7	101.8	290.3	271.9	275.0	27.8	32.0	28.2	62.8	66.4	59.6	100.8	106.4	95.6	302.8	236.7	224.2	201.1	190.5
45	No. 18	1,034	203.5	101.7	271.0	258.0	278.0	28.8	37.0	47.2	59.4	66.0	61.4	95.1	105.5	98.4	299.0	237.3	222.9	201.7	189.3
55	No. 19B	1,123	203.0	101.5	255.0	241.0	265.0	36.2	40.6	36.0	62.0	69.0	60.0	99.5	110.7	95.6	305.8	236.7	223.8	201.1	190.1
128	No. 19C	926																166.0	154.4	141.0	131.2
105	No. 21	1,114																225.5	214.5	191.7	182.2
102	No. 22A	1,081																231.2	217.0	196.5	184.4
98	No. 23A	1,031																233.3	221.5	198.3	188.2
100	No. 23B[c]	998																213.5	203.0	181.5	172.6
103	No. 24B	992																236.0	224.6	200.4	190.8
104	No. 25	959																236.0	223.8	200.6	190.2
126	No. 26	1,015																205.4	192.4	174.5	163.5
127	No. 27	814																147.0	133.5	124.8	113.4
139	No. 29B																	228.7	218.3	194.3	185.6
157	No. 30[c]	958																234.0	225.0	199.0	191.2
	Indiana:																				
14	No. 1	1,061	202.2	101.1	255.8	234.9	252.3	29.3	30.3	27.7	58.6	58.1	53.7	92.3	92.5	85.7	270.5	235.0	221.5	199.9	188.3
13A	No. 2	870	202.0	101.0	212.9	200.7	211.6	28.2	29.5	25.8	51.6	52.6	49.1	82.2	83.7	76.8	242.7	196.0	184.5	166.5	156.8
13B	No. 2	1,092	201.8	100.9	277.5	251.0	223.8	30.0	28.5	27.5	59.0	57.5	53.3	94.0	91.7	85.7	271.4	236.5	225.0	201.0	191.4
53	No. 3[c]	983	196.6	98.3	256.0	263.0	254.0	34.0	36.2	30.9	61.0	65.2	60.2	94.6	101.0	93.4	289.0	223.2	210.0	189.7	178.4
46	No. 5	970	203.2	101.6	275.0	295.0	235.0	27.0	33.0	33.0	59.0	65.0	59.0	95.4	105.1	95.4	295.9	234.2	219.5	199.0	186.5
47	No. 5	967	203.0	101.5														238.0	221.8	202.2	188.4
49	No. 6		203.2	101.6														235.0	222.2	199.6	188.9
51	No. 7A	998	201.0	100.5														233.1	221.4	198.1	188.1
57	No. 8	1,037	202.2	101.1														235.7	223.2	200.2	189.7
52	No. 9A	1,075	200.0	100.0	233.3	285.2	287.6	27.5	29.2	27.6	58.1	66.1	65.1	91.7	104.3	102.7	298.7	230.4	219.1	195.8	186.2
61	No. 11	1,009	203.9	101.9	285.1	284.7	251.7	28.0	31.1	25.7	66.7	62.6	56.9	105.6	100.5	91.2	297.3	235.6	222.9	200.2	189.3
99	No. 12	1,050																228.8	217.9	194.4	185.1
132	No. 13	881																188.2	177.9	160.0	151.2
138	No. 13																	223.2	213.8	189.8	181.7
131	No. 14	985																223.2	212.0	189.8	180.2
134	No. 15	990																223.3	211.8	189.7	180.0
137	No. 15	915																228.0	216.5	193.8	184.0
130	No. 16	941																208.8	197.2	177.4	167.6
133	No. 18B	972																228.8	217.8	194.5	185.1
135	No. 18B	993																231.0	219.9	196.3	186.9
	Indian Territory:																				
1	No. 1	1,140	200.5	100.3	280.5	303.2	283.4	33.4	32.5	30.3	64.9	65.7	63.3	103.5	103.9	99.0	306.4	240.0	230.0	204.0	196.0
20	No. 4	991	203.0	101.5	285.5	270.0	259.0	26.9	25.3	25.5	60.8	58.9	51.6	97.2	94.2	82.5	273.9	234.8	221.2	199.5	188.0
22	Iowa: No. 2	1,105	202.7	101.4	272.0	282.0	272.0	24.0	26.0	24.0	58.0	59.0	54.0	93.0	95.0	87.0	275.0	232.3	219.5	197.5	186.6

[a] Based on an assumed efficiency of 85 per cent for generator and belt.

[b] Mixed with 50 per cent of "front-end" cinders from locomotives in test 33, and with 33⅓ per cent of the same cinders in test 34.

[c] Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Gas horsepower.	Revolutions per minute of gas engine.	Explosions per minute per cylinder.	Indicated horsepower.													Brake horsepower.		Electrical horsepower.	
					Indicator card pressures (pounds per square inch).									Cylinder 1.	Cylinder 2.	Cylinder 3.	Total.	Developed at engine.	Commercially available.	Developed at switchboard.	Commercially available.
					Maximum.			At release.			Mean effective pressure.										
					Cylinder 1.	Cylinder 2.	Cylinder 3.	Cylinder 1.	Cylinder 2.	Cylinder 3.	Cylinder 1.	Cylinder 2.	Cylinder 3.								
1	**2**	**103**	**104**	**105**	**106**	**107**	**108**	**109**	**110**	**111**	**112**	**113**	**114**	**115**	**116**	**117**	**118**	**119**	**120**	**121**	**122**
	Kansas:																				
24	No. 5	1,214	203.1	101.6	280.0	317.0	303.0	23.0	26.0	21.0	53.0	58.0	48.0	85.3	93.3	76.8	255.4	235.5	226.1	200.2	192.2
25	No. 5	964	207.1	103.5	266.0	244.0	224.5	30.0	32.0	34.0	66.5	64.5	55.5	108.4	105.1	90.5	304.0	244.8	232.8	208.0	197.8
101	No. 6	1,068	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	234.0	223.5	198.9	190.0
	Kentucky:																				
79	No. 1B																......	231.7	219.0	196.9	186.2
12	No. 3	1,160	202.0	101.0	277.1	250.3	250.6	28.8	31.5	27.2	57.5	59.3	55.0	91.5	94.5	88.4	274.4	235.5	223.5	200.5	189.8
81	No. 5	1,098	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	233.2	219.2	198.2	186.4
85	No. 6	1,115	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	234.8	220.8	199.5	187.6
84	No. 7	1,016	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	230.0	217.0	195.5	184.3
97	Massachusetts: No. 1	1,217	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	235.5	225.0	200.0	191.1
	Missouri:																				
7A	No. 2	1,123	200.0	100.0	223.3	280.0	200.7	33.0	34.0	30.7	63.3	62.0	54.0	100.6	98.4	86.1	285.1	234.0	221.0	199.0	187.7
7B	No. 2	1,061	198.9	99.5	240.7	278.7	189.7	30.7	31.3	31.0	59.3	58.7	51.0	94.0	92.9	80.8	267.7	233.5	218.5	198.6	185.7
	Montana:																				
5A	No. 1	1,045	201.3	100.6	262.8	280.2	253.8	29.7	29.3	40.0	60.1	58.3	56.0	95.3	92.4	88.6	276.3	234.7	224.8	199.5	191.0
5B	No. 1	876	201.2	100.6	169.3	178.7	160.7	24.7	24.0	26.0	47.3	46.3	47.0	75.3	73.7	74.9	223.9	157.4	148.0	133.8	125.8
149	No. 2	1,026	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	222.2	213.3	188.9	181.4
150	No. 3	1,002	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	234.9	226.8	199.6	192.6
	New Mexico:																				
121	No. 3A	1,033	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	233.5	220.4	198.4	187.3
122	No. 4A	850	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	223.0	209.0	189.5	177.6
120	No. 5	1,112	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	232.0	218.9	197.2	186.0
	North Dakota:																				
68	No. 1B	975	205.2	102.6	......	......	......	......	......	......	......	......	......	......	......	......	......	233.5	216.5	198.4	184.0
10	No. 2	854	201.7	100.8	201.0	204.0	200.5	18.8	23.3	19.8	40.4	43.0	38.2	64.4	68.1	60.6	193.1	158.0	147.3	134.2	125.1
72	No. 2B	......	205.5	102.8	......	......	......	......	......	......	......	......	......	......	......	......	......	230.0	218.7	195.5	185.8
152	No. 2B	990	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	234.4	226.3	199.2	192.4
67	No. 3	987	201.0	100.5	......	......	......	......	......	......	......	......	......	......	......	......	......	230.0	217.8	195.5	185.1

	Ohio:																				
64	No. 3[a]	1,050	205.0	102.5	240.0	203.3	243.3	24.0	36.0	34.7	63.3	52.0	53.3	102.6	84.3	86.5	273.4	236.4	221.0	200.8	187.9
60	No. 4	1,040	202.1	101.1	240.0	265.0	285.0	38.0	42.5	34.5	63.5	63.5	61.5	100.7	100.7	97.6	299.0	238.2	226.3	202.4	192.3
58	No. 5	1,028	203.0	101.5	246.0	243.0	304.0	27.0	30.5	25.6	62.7	70.7	54.5	100.4	113.1	87.3	300.8	238.0	224.0	202.2	190.3
76	No. 6	1,068																230.1	219.2	195.6	186.3
87	No. 7	1,061																233.0	221.0	198.0	187.9
83	No. 8	1,098																233.8	217.9	198.6	185.1
73	No. 9A		202.8	101.4														229.0	217.0	194.5	184.4
142	No. 10	1,036																234.0	225.1	199.0	191.4
145	No. 11	1,015																234.8	224.9	199.5	191.1
146	No. 12	1,050																234.0	223.5	198.8	189.9
147	No. 12	993																233.7	224.2	198.6	190.6
	Pennsylvania:																				
65	No. 4	1,003	203.2	101.6														229.7	218.4	195.1	185.6
59	No. 5B	970	202.7	101.4	269.0	223.0	266.0	34.9	41.8	34.6	62.2	66.0	60.8	99.6	105.7	97.3	302.6	239.0	223.8	203.0	190.1
66	No. 6[a]	884	201.9	100.9	290.0	242.5	277.5	38.0	41.0	37.5	69.0	63.0	58.5	109.9	100.3	93.2	303.4	229.9	213.1	195.3	181.2
70	Nos. 6A and 6B	946	203.2	101.6														228.5	216.0	194.2	183.5
88	No. 7	927																200.0	187.5	169.9	159.3
63	No. 8	1,015	200.2	100.1														221.0	208.8	187.9	177.4
71	No. 10	977	206.3	103.2														231.0	220.0	196.3	186.8
129	No. 11	1,003																200.9	188.1	170.7	159.9
143	No. 12	1,010																229.8	220.5	195.3	187.4
136	No. 13	980																227.3	217.4	193.2	184.8
140	No. 13	1,006																231.2	221.4	196.5	188.2
144	No. 15	1,023																225.5	216.8	191.8	184.3
148	No. 16	1,030																234.3	224.4	199.2	190.7
158	No. 17	939																221.7	213.0	188.4	181.1
159	No. 22	981																232.5	223.8	197.7	190.2
113	Rhode Island: No. 1																				
	Tennessee:																				
115	No. 1																	198.8		169.0	
107	No. 2	1,150																237.0	224.8	201.3	190.9
106	No. 3	1,112																236.5	221.2	201.0	188.0
111	No. 4	1,058																214.2	201.4	182.0	171.1
125	No. 5	1,018																219.7	205.5	186.7	174.7
110	No. 6	906																183.5	169.5	156.0	144.1
108	No. 7A	1,109																226.5	212.2	192.5	180.4
116	Nos. 8A and 8B[a]																	170.2		144.6	
119	Nos. 8A and 8B[a]	1,135																231.8	217.4	197.0	184.7
	Texas:																				
11	No. 1	1,101	201.5	100.7	274.0	253.0	248.8	27.9	30.7	27.8	56.6	58.3	55.0	88.9	92.6	87.3	268.8	233.0	220.0	198.0	187.0
18	No. 2	982	201.6	100.8	241.0	271.0	255.0	31.0	28.3	26.0	61.0	58.2	52.8	96.7	92.5	83.7	272.9	236.5	233.0	201.2	189.6
93	No. 3	1,099																235.5	222.6	200.1	189.2
92	No. 4																	227.5	217.5	193.4	184.9
118	Utah: No. 1	1,138																242.7	229.8	206.2	195.2

[a] Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Gas horsepower.	Revolutions per minute of gas engine.	Explosions per minute per cylinder.	Indicated horsepower.													Brake horsepower.		Electrical horsepower.	
					Indicator card pressures (pounds per square inch).									Cylinder 1.	Cylinder 2.	Cylinder 3.	Total.	Developed at engine.	Commercially available.	Developed at switchboard.	Commercially available.
					Maximum.			At release.			Mean effective pressure.										
					Cylinder 1.	Cylinder 2.	Cylinder 3.	Cylinder 1.	Cylinder 2.	Cylinder 3.	Cylinder 1.	Cylinder 2.	Cylinder 3.								
1	2	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122
	Virginia:																				
77	No. 1	1,073	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	231.0	219.2	196.2	186.3
78	No. 2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	232.5	219.0	197.5	186.0
75	No. 3	1,027	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	229.2	215.5	194.8	183.2
74	No. 4	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	231.0	218.9	196.3	186.0
154	No. 5A	942	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	234.9	227.0	199.6	192.9
160	No. 6	934	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	227.1	220.3	193.1	187.3
163	Jamestown, No. 1	1,083	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	239.0	232.7	203.1	197.8
	Washington:																				
90	No. 1A[a]	900	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	169.7	157.7	144.2	134.0
89	No. 1B	1,070	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	183.8	171.4	156.2	145.6
94	No. 1B	1,012	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	230.1	218.5	195.6	185.6
112	No. 2	1.022	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	230.2	217.8	195.7	185.0
	West Virginia:																				
3	No. 1	1,029	200.9	100.5	242.0	244.8	240.8	30.9	31.2	30.0	61.1	59.8	56.6	96.7	94.7	89.7	281.1	235.5	223.8	200.4	190.1
4	No. 4	1,044	200.7	100.3	269.6	285.0	268.5	31.0	33.2	29.2	62.6	65.0	55.2	98.9	102.8	87.1	288.8	235.0	222.5	199.7	189.2
23	No. 7	1,323	202.3	101.2	238.0	217.0	271.0	26.0	27.5	25.7	58.5	59.0	52.0	93.6	94.1	84.3	272.0	234.1	221.0	199.1	187.7
19	No. 8	1,138	202.0	101.0	238.0	233.0	257.0	28.0	29.0	25.7	60.5	61.2	53.3	96.3	97.4	84.9	278.6	235.0	224.0	199.9	190.3
17A	No. 9	934	202.5	101.3	210.0	220.0	220.0	25.7	27.3	23.9	54.0	56.3	48.3	86.2	89.9	77.1	253.2	198.0	181.4	168.3	154.1
17B	No. 9	935	203.0	101.5	305.0	261.0	212.0	30.0	30.5	27.2	62.5	61.4	52.8	99.8	98.2	84.2	282.2	236.5	220.0	201.0	186.9
21	No. 9	1,092	202.5	101.3	255.0	235.0	255.0	27.0	25.0	23.0	59.8	61.0	49.8	95.0	96.9	79.1	271.0	234.4	222.1	199.3	189.0
161	No. 11B	941	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	228.8	222.0	194.3	188.8
8	No. 12	1,061	203.7	101.8	260.4	283.9	233.9	27.7	32.3	28.9	59.8	57.8	50.1	95.8	92.7	80.4	268.9	235.0	225.0	199.8	191.3
56	No. 13	1,074	199.6	99.8	215.0	266.0	276.0	27.9	30.6	28.7	56.1	67.9	59.3	89.0	107.6	93.9	290.5	236.0	223.5	200.5	189.9
54	No. 14	1,077	199.6	99.8	279.0	287.0	301.0	28.5	30.5	29.5	64.8	75.0	47.0	101.2	116.9	73.4	291.5	237.0	225.8	201.3	191.9
86	No. 16A	1,035	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	233.6	219.7	198.5	186.7
80	No. 18	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	233.0	220.0	197.9	186.8
82	No. 20	1,110	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	231.0	218.0	196.3	185.2

162	No. 24	706																175.2	166.9	148.8	141.9
156	No. 25	954																234.4	226.0	199.2	192.1
164	Jamestown, No. 3	1,007																236.2	230.0	200.8	195.4
165	Jamestown, No. 4	1,013																239.2	231.9	203.3	197.1
166	Jamestown, No. 5	1,038																235.3	229.0	200.0	194.7
167	Jamestown, No. 7	1,085																230.8	224.1	196.2	190.5
168	Jamestown, No. 7	1,075																235.8	229.2	200.5	194.8
	Wyoming:																				
16	No. 2	885	203.2	101.6	244.5	262.6	241.2	27.4	28.6	26.8	57.7	56.0	50.4	92.3	90.3	80.7	263.3	236.8	217.4	201.2	184.8
62	No. 2B	1,000	202.4	101.2														227.0	215.2	192.9	182.9
69	No 3	1,040	202.7	101.4														227.2	212.3	193.1	180.4
123	No. 4																	230.0	216.5	195.5	184.0
114	No. 5	1,065																228.8	214.0	194.5	181.9
124	No. 6																	235.2	222.0	200.0	188.6
	Miscellaneous:																				
151	Coke																	234.8		199.5	
50	Coke breeze	1,090	201.0	100.5														227.5	215.0	193.3	182.6
153	Refuse																				

a Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Economic results: Fuel charged in producer per horsepower hour (pounds).												Economic results: Total fuel used by producer plant per horsepower hour (pounds).											
		Per brake horsepower.						Per electrical horsepower.						Per brake horsepower.						Per electrical horsepower.					
		Developed at engine.			Commercially available.			Developed at switchboard.			Commercially available.			Developed at engine.			Commercially available.			Developed at switchboard.			Commercially available.		
		As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.
1	2	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
	Alabama:																								
2	No. 2	1.32	1.27	1.14	1.37	1.32	1.19	1.55	1.49	1.34	1.61	1.55	1.40	1.45	1.40	1.26	1.51	1.45	1.31	1.71	1.64	1.48	1.77	1.71	1.54
109	No. 4	1.06	1.03	.90	1.13	1.09	.95	1.25	1.21	1.06	1.33	1.29	1.12	1.16	1.12	.97	1.23	1.19	1.04	1.36	1.32	1.15	1.45	1.40	1.22
155	No. 6	1.03	1.00	.93	1.06	1.03	.96	1.21	1.18	1.10	1.25	1.22	1.13	1.10	1.07	1.00	1.13	1.11	1.03	1.29	1.26	1.17	1.33	1.30	1.21
	Argentina:																								
141	Argentina (special)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
169	Jamestown No. 8	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
	Arkansas:																								
96	No. 7A	1.60	1.53	1.34	1.75	1.67	1.46	1.88	1.80	1.57	2.06	1.97	1.72	1.74	1.66	1.45	1.90	1.82	1.59	2.04	1.96	1.71	2.24	2.14	1.87
95	No. 8	1.58	1.54	1.29	1.66	1.62	1.36	1.86	1.81	1.52	1.96	1.90	1.60	1.72	1.67	1.40	1.81	1.76	1.48	2.02	1.97	1.65	2.13	2.07	1.74
91	No. 10	3.03	1.83	1.54	3.29	1.99	1.67	3.56	2.16	1.81	3.87	2.34	1.96	3.43	2.09	1.76	3.75	2.27	1.91	4.07	2.46	2.07	4.41	2.67	2.24
44	Brazil No. 1	2.02	1.80	1.33	2.24	1.99	1.47	2.38	2.12	1.56	2.63	2.35	1.73	2.21	1.97	1.45	2.45	2.18	1.61	2.60	2.32	1.71	2.88	2.56	1.89
	California:																								
32	No. 1	2.33	1.92	1.56	2.48	2.05	1.66	2.74	2.26	1.84	2.91	2.41	1.96	2.45	2.02	1.65	2.60	2.15	1.75	2.88	2.38	1.94	3.06	2.53	2.06
33	No. 1 *a*	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
34	No. 1 *a*	2.04	1.77	1.46	2.13	1.85	1.52	2.40	2.08	1.71	2.50	2.17	1.79	......	......	......	......	......	......	......	......	......	......	......	......
15	Colorado No. 1	1.55	1.23	1.14	1.66	1.32	1.23	1.82	1.45	1.35	1.95	1.56	1.45	1.82	1.45	1.34	1.95	1.56	1.44	2.14	1.71	1.58	2.30	1.83	1.70
117	Florida No. 1	2.43	1.92	1.79	2.53	2.00	1.87	2.85	2.25	2.11	2.98	2.35	2.20	2.57	2.03	1.90	2.69	2.12	1.98	3.03	2.39	2.24	3.16	2.50	2.33
	Illinois:																								
6	No. 3	1.49	1.38	1.23	1.54	1.43	1.28	1.75	1.62	1.45	1.82	1.68	1.50	1.64	1.52	1.36	1.70	1.58	1.41	1.93	1.79	1.60	2.01	1.85	1.66
9	No. 4	1.50	1.31	1.17	1.57	1.37	1.23	1.76	1.55	1.38	1.85	1.62	1.45	1.71	1.50	1.34	1.79	1.56	1.40	2.01	1.76	1.57	2.11	1.85	1.65
35	No. 6B	1.61	1.42	1.16	1.70	1.50	1.23	1.89	1.67	1.37	2.00	1.77	1.45	1.72	1.52	1.25	1.82	1.61	1.31	2.02	1.79	1.46	2.14	1.89	1.55
26	No. 7A	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
27	No. 7B	1.89	1.67	1.34	1.98	1.75	1.40	2.23	1.97	1.58	2.33	2.06	1.65	2.05	1.81	1.45	2.14	1.89	1.51	2.41	2.12	1.70	2.52	2.22	1.78
38	No. 7C	2.32	2.09	1.65	2.49	2.24	1.77	2.73	2.45	1.94	2.93	2.63	2.08	2.47	2.22	1.75	2.65	2.38	1.88	2.91	2.61	2.06	3.12	2.80	2.21
29	No. 8	1.56	1.36	1.18	1.64	1.43	1.24	1.84	1.60	1.39	1.93	1.68	1.46	1.68	1.47	1.27	1.77	1.54	1.34	1.98	1.72	1.50	2.08	1.81	1.57

28	No. 9B	1.61	1.42	1.23	1.70	1.49	1.30	1.90	1.67	1.45	1.99	1.76	1.53	1.71	1.50	1.31	1.79	1.58	1.37	2.01	1.77	1.54	2.11	1.86	1.62
31	No. 10	1.28	1.17	1.03	1.36	1.24	1.10	1.50	1.38	1.22	1.60	1.46	1.29	1.35	1.23	1.09	1.44	1.31	1.16	1.59	1.45	1.28	1.69	1.54	1.36
30	No. 11A	1.18	1.10	.97	1.26	1.18	1.04	1.39	1.29	1.14	1.49	1.38	1.22	1.24	1.15	1.02	1.33	1.23	1.09	1.46	1.36	1.19	1.56	1.45	1.28
36	No. 11C [b]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
42	No. 11D [b]	1.07	.97	.90	1.14	1.04	.96	1.25	1.15	1.05	1.34	1.22	1.12	1.17	1.07	.98	1.25	1.14	1.05	1.38	1.26	1.16	1.47	1.34	1.24
48	No. 11D [b]	1.05	.96	.89	1.11	1.02	.94	1.23	1.13	1.04	1.31	1.20	1.11	1.16	1.07	.99	1.24	1.14	1.05	1.37	1.26	1.16	1.46	1.34	1.24
41	No. 13	1.38	1.26	1.12	1.46	1.33	1.18	1.63	1.48	1.32	1.72	1.57	1.39	1.48	1.35	1.20	1.56	1.42	1.26	1.74	1.59	1.41	1.84	1.68	1.49
37	No. 14	1.42	1.24	1.07	1.51	1.32	1.13	1.67	1.46	1.25	1.78	1.55	1.33	1.52	1.33	1.14	1.61	1.41	1.21	1.79	1.56	1.34	1.90	1.66	1.42
39	No. 15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
40	No. 15	1.44	1.30	1.11	1.53	1.39	1.18	1.69	1.53	1.30	1.80	1.63	1.39	1.53	1.38	1.16	1.63	1.47	1.23	1.80	1.63	1.36	1.90	1.73	1.45
43	No. 16	1.46	1.35	1.19	1.54	1.42	1.26	1.72	1.58	1.41	1.81	1.67	1.48	1.54	1.42	1.26	1.62	1.50	1.33	1.81	1.67	1.48	1.91	1.77	1.57
45	No. 18	1.37	1.19	1.05	1.45	1.26	1.12	1.61	1.40	1.23	1.71	1.49	1.31	1.48	1.28	1.13	1.57	1.36	1.21	1.74	1.51	1.33	1.85	1.61	1.42
55	No. 19B	1.18	1.07	.95	1.25	1.13	1.01	1.39	1.26	1.12	1.47	1.33	1.19	1.25	1.13	1.01	1.32	1.19	1.07	1.47	1.33	1.19	1.55	1.40	1.26
128	No. 19C	1.74	1.57	1.39	1.87	1.68	1.49	2.04	1.84	1.64	2.20	1.98	1.76	1.90	1.71	1.52	2.04	1.84	1.63	2.23	2.01	1.78	2.40	2.16	1.92
105	No. 21	1.64	1.40	1.22	1.73	1.47	1.28	1.93	1.65	1.43	2.04	1.74	1.50	1.76	1.50	1.30	1.85	1.58	1.37	2.07	1.77	1.53	2.18	1.86	1.61
102	No. 22A	1.50	1.33	1.13	1.60	1.42	1.21	1.77	1.57	1.33	1.88	1.67	1.42	1.59	1.41	1.20	1.70	1.51	1.28	1.88	1.66	1.42	2.00	1.77	1.51
98	No. 23A	1.54	1.36	1.18	1.63	1.43	1.24	1.82	1.60	1.38	1.91	1.69	1.46	1.63	1.43	1.24	1.71	1.51	1.31	1.91	1.69	1.46	2.02	1.78	1.54
100	No. 23B [b]	1.62	1.38	1.23	1.70	1.45	1.29	1.90	1.62	1.45	2.00	1.70	1.52	1.76	1.50	1.34	1.85	1.57	1.41	2.07	1.76	1.57	2.17	1.85	1.66
103	No. 24B	1.24	1.10	.97	1.31	1.16	1.02	1.46	1.29	1.14	1.54	1.36	1.19	1.32	1.17	1.03	1.39	1.23	1.08	1.55	1.38	1.21	1.63	1.45	1.27
104	No. 25	1.36	1.20	1.02	1.43	1.27	1.08	1.60	1.41	1.20	1.68	1.49	1.27	1.43	1.27	1.08	1.51	1.34	1.14	1.68	1.49	1.27	1.78	1.58	1.34
126	No. 26	1.56	1.36	1.11	1.67	1.45	1.18	1.84	1.59	1.30	1.96	1.70	1.39	1.70	1.47	1.20	1.81	1.57	1.28	2.00	1.73	1.41	2.13	1.85	1.51
127	No. 27	2.19	1.94	1.63	2.40	2.13	1.80	2.57	2.28	1.92	2.83	2.51	2.12	2.36	2.10	1.77	2.60	2.31	1.95	2.78	2.47	2.08	3.06	2.72	2.29
139	No. 29B	1.51	1.33	1.14	1.58	1.39	1.19	1.78	1.56	1.34	1.86	1.63	1.40	1.62	1.42	1.22	1.70	1.49	1.28	1.91	1.67	1.44	2.00	1.75	1.51
157	No. 30 [b]	1.38	1.31	1.17	1.44	1.36	1.22	1.63	1.54	1.38	1.69	1.60	1.44	1.45	1.37	1.23	1.51	1.43	1.28	1.71	1.61	1.45	1.78	1.68	1.51
	Indiana:																								
14	No. 1	1.68	1.49	1.32	1.78	1.58	1.40	1.97	1.75	1.55	2.10	1.86	1.64	1.85	1.64	1.45	1.96	1.74	1.54	2.17	1.93	1.71	2.31	2.04	1.81
13A	No. 2	1.68	1.53	1.37	1.78	1.63	1.45	1.97	1.80	1.61	2.10	1.91	1.71	1.89	1.73	1.54	2.01	1.83	1.64	2.22	2.03	1.81	2.36	2.16	1.93
13B	No. 2	1.27	1.16	1.03	1.33	1.22	1.09	1.49	1.36	1.22	1.57	1.43	1.28	1.43	1.32	1.18	1.50	1.39	1.24	1.68	1.55	1.39	1.77	1.63	1.46
53	No. 3 [b]	1.57	1.39	1.26	1.67	1.47	1.34	1.85	1.63	1.48	1.97	1.74	1.57	1.67	1.47	1.33	1.78	1.56	1.42	1.97	1.73	1.57	2.09	1.84	1.67
46	No. 5	1.69	1.52	1.31	1.80	1.62	1.39	1.99	1.79	1.54	2.12	1.91	1.64	1.83	1.64	1.41	1.95	1.75	1.51	2.15	1.93	1.66	2.29	2.06	1.78
47	No. 5	1.20	1.07	.95	1.29	1.15	1.02	1.41	1.26	1.12	1.51	1.35	1.20	1.28	1.15	1.01	1.37	1.23	1.09	1.51	1.35	1.19	1.62	1.45	1.28
49	No. 6	1.52	1.35	1.16	1.61	1.43	1.23	1.79	1.59	1.27	1.89	1.68	1.45	1.65	1.47	1.26	1.74	1.55	1.33	1.94	1.73	1.49	2.05	1.83	1.57
51	No. 7A	1.30	1.20	1.06	1.37	1.26	1.12	1.53	1.41	1.25	1.61	1.49	1.32	1.40	1.26	1.14	1.47	1.36	1.20	1.65	1.52	1.35	1.74	1.60	1.42
57	No. 8	1.30	1.18	1.03	1.37	1.24	1.09	1.53	1.39	1.22	1.61	1.46	1.28	1.37	1.24	1.09	1.45	1.31	1.15	1.61	1.46	1.28	1.70	1.54	1.35
52	No. 9A	1.49	1.30	1.15	1.57	1.37	1.21	1.75	1.53	1.36	1.84	1.61	1.43	1.57	1.35	1.21	1.65	1.44	1.27	1.84	1.61	1.43	1.94	1.70	1.50
61	No. 11	1.35	1.18	1.06	1.43	1.25	1.13	1.59	1.39	1.25	1.68	1.46	1.32	1.47	1.28	1.16	1.56	1.35	1.22	1.73	1.51	1.36	1.83	1.59	1.44
99	No. 12	1.50	1.35	1.16	1.58	1.41	1.22	1.77	1.59	1.36	1.86	1.66	1.43	1.59	1.43	1.23	1.67	1.50	1.29	1.87	1.68	1.44	1.97	1.76	1.52
132	No. 13	1.63	1.44	1.23	1.72	1.52	1.30	1.91	1.69	1.44	2.02	1.79	1.52	1.77	1.57	1.33	1.88	1.66	1.41	2.09	1.85	1.57	2.21	1.95	1.66
138	No. 13	1.26	1.13	.99	1.32	1.18	1.03	1.48	1.32	1.16	1.55	1.38	1.21	1.37	1.22	1.07	1.43	1.27	1.12	1.61	1.44	1.26	1.68	1.50	1.32
131	No. 14	1.45	1.34	1.13	1.53	1.41	1.19	1.71	1.57	1.33	1.80	1.66	1.40	1.54	1.42	1.20	1.62	1.49	1.26	1.81	1.67	1.41	1.91	1.76	1.49
134	No. 15	1.31	1.16	1.05	1.38	1.23	1.11	1.55	1.37	1.24	1.63	1.44	1.30	1.41	1.25	1.12	1.48	1.32	1.18	1.66	1.47	1.32	1.75	1.55	1.39
137	No. 15	1.23	1.09	.99	1.30	1.15	1.04	1.45	1.29	1.16	1.53	1.35	1.22	1.33	1.18	1.06	1.40	1.24	1.12	1.56	1.38	1.25	1.65	1.46	1.32
130	No. 16	1.54	1.42	1.24	1.63	1.51	1.31	1.82	1.68	1.46	1.92	1.77	1.54	1.66	1.53	1.33	1.75	1.62	1.41	1.95	1.80	1.57	2.06	1.90	1.66
133	No. 18B	1.26	1.12	1.03	1.32	1.17	1.08	1.48	1.31	1.21	1.55	1.38	1.27	1.35	1.20	1.11	1.42	1.26	1.16	1.59	1.41	1.30	1.67	1.48	1.37
135	No. 18B	1.42	1.24	1.15	1.49	1.31	1.21	1.67	1.46	1.35	1.75	1.54	1.42	1.52	1.34	1.23	1.60	1.40	1.29	1.79	1.57	1.45	1.88	1.65	1.52
	Indian Territory:																								
1	No. 1	1.50	1.43	1.30	1.57	1.50	1.36	1.77	1.69	1.53	1.84	1.76	1.59	1.64	1.56	1.41	1.71	1.62	1.47	1.92	1.83	1.66	2.00	1.91	1.73
20	No. 4	1.18	1.08	.89	1.26	1.15	.94	1.39	1.27	1.04	1.48	1.35	1.10	1.33	1.21	1.00	1.41	1.29	1.06	1.57	1.43	1.17	1.66	1.51	1.24

[a] Mixed with 50 per cent of "front-end" cinders from locomotives in test 33 and with 33⅓ per cent of the samecinders in test 34.
[b] Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Economic results: Fuel charged in producer per horsepower hour (pounds).												Economic results: Total fuel used by producer plant per horsepower hour (pounds).											
		Per brake horsepower.						Per electrical horsepower.						Per brake horsepower.						Per electrical horsepower.					
		Developed at engine.			Commercially available.			Developed at switchboard.			Commercially available.			Developed at engine.			Commercially available.			Developed at switchboard.			Commercially available.		
		As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.
1	**2**	**127**	**128**	**129**	**130**	**131**	**132**	**133**	**134**	**135**	**136**	**137**	**138**	**139**	**140**	**141**	**142**	**143**	**144**	**145**	**146**	**147**	**148**	**149**	**150**
22	Iowa No. 2	1.56	1.30	.98	1.65	1.38	1.04	1.84	1.53	1.15	1.94	1.62	1.22	1.76	1.47	1.10	1.86	1.55	1.17	2.07	1.73	1.30	2.19	1.83	1.37
	Kansas:																								
24	No. 5	1.31	1.25	1.10	1.36	1.30	1.15	1.54	1.47	1.30	1.60	1.53	1.35	1.44	1.37	1.21	1.50	1.43	1.26	1.69	1.62	1.43	1.76	1.68	1.49
25	No. 5	1.18	1.13	1.01	1.24	1.19	1.06	1.39	1.33	1.19	1.46	1.40	1.25	1.33	1.27	1.14	1.40	1.34	1.20	1.57	1.50	1.34	1.65	1.58	1.41
101	No. 6	1.41	1.27	1.08	1.47	1.33	1.13	1.66	1.49	1.27	1.73	1.56	1.33	1.49	1.35	1.15	1.56	1.41	1.20	1.76	1.58	1.35	1.84	1.66	1.41
	Kentucky:																								
79	No. 1B	1.13	1.10	1.06	1.19	1.16	1.12	1.33	1.29	1.25	1.40	1.37	1.32	1.19	1.16	1.12	1.26	1.23	1.19	1.41	1.37	1.32	1.49	1.45	1.40
12	No. 3	1.57	1.46	1.32	1.66	1.54	1.39	1.85	1.71	1.55	1.95	1.81	1.63	1.75	1.62	1.46	1.84	1.71	1.54	2.05	1.91	1.72	2.16	2.01	1.81
81	No. 5	1.11	1.07	1.02	1.18	1.13	1.08	1.30	1.25	1.20	1.38	1.33	1.28	1.18	1.13	1.08	1.25	1.20	1.15	1.39	1.33	1.28	1.47	1.42	1.36
85	No. 6	1.07	1.03	.99	1.14	1.09	1.05	1.26	1.21	1.16	1.34	1.28	1.24	1.13	1.08	1.04	1.20	1.15	1.11	1.33	1.27	1.23	1.42	1.35	1.30
84	No. 7	1.33	1.22	1.09	1.41	1.29	1.16	1.57	1.43	1.28	1.66	1.52	1.36	1.40	1.29	1.15	1.49	1.36	1.22	1.65	1.51	1.35	1.75	1.60	1.44
97	Massachusetts No. 1	3.06	1.54	1.17	3.20	1.61	1.22	3.60	1.81	1.38	3.77	1.89	1.44	......	......	......	......	......	......	......	......	......	......	......	......
	Missouri:																								
7A	No. 2	3.23	1.98	1.64	2.36	2.09	1.74	2.62	2.32	1.93	2.78	2.46	2.05	2.48	2.19	1.83	2.62	2.32	1.93	2.91	2.58	2.14	3.09	2.73	2.27
7B	No. 2	1.48	1.31	1.09	1.59	1.40	1.17	1.74	1.54	1.28	1.87	1.65	1.37	1.65	1.45	1.21	1.76	1.55	1.30	1.94	1.71	1.43	2.07	1.83	1.52
	Montana:																								
5A	No. 1	1.95	1.72	1.52	2.03	1.80	1.58	2.29	2.03	1.78	2.39	2.12	1.86	2.16	1.91	1.68	2.26	2.00	1.76	2.54	2.25	1.98	2.65	2.35	2.07
5B	No. 1	2.45	2.17	1.91	2.61	2.31	2.03	2.88	2.56	2.24	3.07	2.72	2.38	2.70	2.39	2.10	2.88	2.55	2.23	3.18	2.81	2.47	3.38	3.00	2.63
149	No. 2	1.74	1.59	1.32	1.81	1.66	1.38	2.05	1.87	1.56	2.13	1.95	1.62	1.91	1.75	1.45	1.99	1.82	1.52	2.25	2.06	1.71	2.34	2.14	1.78
150	No. 3	1.39	1.27	1.08	1.44	1.31	1.12	1.63	1.49	1.27	1.69	1.55	1.32	1.48	1.35	1.15	1.53	1.40	1.20	1.74	1.59	1.36	1.80	1.65	1.41
	New Mexico:																								
121	No. 3A	1.10	1.06	.85	1.17	1.12	.90	1.30	1.25	.99	1.37	1.32	1.05	1.18	1.14	.91	1.25	1.21	.96	1.39	1.34	1.07	1.47	1.42	1.13
122	No. 4A	1.18	1.15	.99	1.25	1.22	1.05	1.38	1.35	1.16	1.48	1.44	1.24	1.29	1.26	1.08	1.38	1.34	1.16	1.52	1.48	1.28	1.62	1.58	1.36
120	No. 5	1.20	1.18	.99	1.27	1.25	1.05	1.41	1.38	1.17	1.49	1.47	1.24	1.29	1.26	1.06	1.36	1.34	1.13	1.51	1.48	1.25	1.60	1.57	1.33
	North Dakota:																								
68	No. 1B	2.27	1.53	1.27	2.45	1.65	1.37	2.67	1.80	1.50	2.88	1.94	1.61	2.40	1.61	1.34	2.58	1.74	1.45	2.82	1.90	1.53	3.04	2.05	1.70
10	No. 2	2.91	1.76	1.58	3.13	1.89	1.69	3.42	2.07	1.86	3.67	2.22	1.99	2.23	1.95	1.74	3.47	2.09	1.88	3.80	2.29	2.05	4.07	2.46	2.20

72	No. 2B	2.26	1.44	1.33	2.38	1.52	1.40	2.66	1.70	1.57	2.80	1.79	1.65	2.40	1.53	1.41	2.53	1.61	1.49	2.83	1.80	1.66	2.97	1.90	1.75
152	No. 2B	2.28	1.39	1.27	2.36	1.44	1.31	2.68	1.64	1.49	2.77	1.89	1.55	2.44	1.49	1.36	2.53	1.54	1.41	2.87	1.75	1.60	2.97	1.82	1.66
67	No. 3	2.63	1.69	1.52	2.78	1.78	1.61	3.10	1.99	1.79	3.27	2.10	1.89	2.75	1.77	1.59	2.92	1.87	1.68	3.24	2.08	1.78	3.42	2.20	1.98
	Ohio:																								
64	No. 3 [a]	1.21	1.11	1.01	1.29	1.18	1.08	1.42	1.30	1.19	1.52	1.39	1.28	1.28	1.18	1.08	1.37	1.26	1.16	1.51	1.39	1.27	1.62	1.48	1.36
60	No. 4	1.06	1.01	.92	1.11	1.06	.97	1.25	1.18	1.09	1.31	1.24	1.14	1.14	1.08	.99	1.20	1.13	1.04	1.34	1.27	1.17	1.41	1.33	1.23
58	No. 5	1.00	.95	.89	1.06	1.01	.95	1.17	1.12	1.05	1.25	1.19	1.12	1.07	1.02	.96	1.13	1.09	1.02	1.26	1.20	1.13	1.34	1.28	1.20
76	No. 6	1.03	.99	.90	1.08	1.04	.95	1.21	1.17	1.06	1.27	1.23	1.12	1.10	1.06	.97	1.16	1.12	1.02	1.30	1.25	1.14	1.36	1.31	1.20
87	No. 7	1.35	1.27	1.16	1.42	1.34	1.23	1.58	1.50	1.37	1.67	1.58	1.44	1.42	1.35	1.23	1.50	1.41	1.30	1.67	1.58	1.45	1.76	1.67	1.52
83	No. 8	1.27	1.17	1.01	1.36	1.25	1.08	1.50	1.37	1.19	1.60	1.47	1.27	1.32	1.21	1.05	1.42	1.30	1.12	1.56	1.42	1.23	1.67	1.53	1.32
73	No. 9A	1.12	1.04	.95	1.18	1.10	1.00	1.32	1.22	1.11	1.39	1.29	1.17	1.21	1.13	1.03	1.28	1.19	1.08	1.43	1.32	1.21	1.51	1.40	1.27
142	No. 10	1.08	1.04	.94	1.12	1.08	.98	1.27	1.22	1.11	1.32	1.27	1.15	1.15	1.10	1.00	1.19	1.15	1.04	1.35	1.30	1.18	1.40	1.35	1.22
145	No. 11	1.18	1.14	.99	1.23	1.19	1.03	1.39	1.34	1.16	1.45	1.40	1.21	1.26	1.22	1.06	1.32	1.27	1.10	1.49	1.44	1.24	1.55	1.50	1.30
146	No. 12	1.34	1.30	1.17	1.40	1.36	1.22	1.58	1.53	1.37	1.65	1.60	1.44	1.43	1.39	1.25	1.50	1.46	1.31	1.69	1.64	1.47	1.77	1.72	1.54
147	No. 12	1.23	1.18	1.05	1.28	1.23	1.09	1.45	1.39	1.23	1.51	1.45	1.28	1.32	1.27	1.13	1.38	1.33	1.18	1.56	1.50	1.33	1.62	1.56	1.38
	Pennsylvania:																								
65	No. 4	1.15	1.13	1.00	1.21	1.19	1.05	1.35	1.33	1.18	1.42	1.40	1.24	1.21	1.18	1.05	1.27	1.24	1.10	1.42	1.39	1.24	1.49	1.46	1.30
59	No. 5B	1.02	.98	.90	1.09	1.05	.97	1.20	1.16	1.06	1.28	1.24	1.14	1.09	1.05	.97	1.16	1.12	1.03	1.28	1.24	1.14	1.37	1.32	1.21
66	No. 6 [a]	1.20	1.18	1.09	1.30	1.27	1.17	1.42	1.39	1.28	1.53	1.50	1.38	1.28	1.26	1.16	1.38	1.35	1.25	1.51	1.48	1.36	1.63	1.59	1.47
70	No. 6A and 6B	.99	.96	.84	1.04	1.01	.89	1.16	1.13	.99	1.23	1.19	1.05	1.04	1.01	.89	1.10	1.07	.94	1.23	1.19	1.05	1.30	1.26	1.11
88	No. 7	1.34	1.29	1.12	1.42	1.31	1.19	1.57	1.52	1.32	1.68	1.62	1.41	1.42	1.37	1.19	1.52	1.47	1.27	1.68	1.62	1.41	1.79	1.72	1.50
63	No. 8	1.00	.98	.91	1.06	1.04	.96	1.18	1.15	1.07	1.25	1.22	1.13	1.09	1.06	.98	1.15	1.12	1.04	1.28	1.25	1.15	1.35	1.32	1.22
71	No. 10	1.07	1.04	.95	1.12	1.09	.99	1.25	1.22	1.11	1.32	1.28	1.17	1.12	1.09	.99	1.18	1.14	1.04	1.32	1.28	1.17	1.38	1.35	1.23
129	No. 11	1.22	1.19	1.10	1.30	1.27	1.18	1.43	1.40	1.30	1.53	1.50	1.39	1.32	1.29	1.20	1.41	1.38	1.28	1.55	1.52	1.41	1.66	1.63	1.51
143	No. 12	.95	.93	.84	.99	.97	.88	1.12	1.09	.99	1.16	1.14	1.03	1.05	1.03	.93	1.09	1.07	.97	1.23	1.21	1.09	1.28	1.26	1.14
136	No. 13	1.11	1.08	.93	1.16	1.13	.98	1.30	1.27	1.10	1.36	1.33	1.15	1.21	1.18	1.02	1.26	1.23	1.06	1.42	1.39	1.20	1.49	1.45	1.25
140	No. 13	1.02	1.00	.88	1.06	1.04	.92	1.20	1.18	1.03	1.25	1.23	1.08	1.10	1.09	.95	1.16	1.14	1.00	1.30	1.28	1.12	1.36	1.34	1.17
144	No. 15	1.05	1.03	.92	1.10	1.07	.96	1.24	1.21	1.08	1.29	1.26	1.12	1.17	1.14	1.02	1.22	1.18	1.06	1.37	1.34	1.20	1.43	1.39	1.25
148	No. 16	.85	.80	.74	.89	.84	.77	1.00	.95	.87	1.04	.99	.90	.95	.90	.82	.99	.94	.86	1.12	1.06	.97	1.17	1.11	1.01
158	No. 17	1.19	1.14	.99	1.24	1.19	1.03	1.40	1.34	1.16	1.46	1.39	1.21	1.26	1.21	1.05	1.31	1.26	1.09	1.49	1.42	1.23	1.55	1.48	1.28
159	No. 22	1.01	.97	.86	1.05	1.00	.90	1.18	1.14	1.02	1.23	1.18	1.06	1.07	1.03	.92	1.11	1.07	.95	1.26	1.21	1.08	1.31	1.26	1.12
113	Rhode Island No. 1	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
	Tennessee:																								
115	No. 1	1.24	1.20	1.05	......	......	......	1.46	1.42	1.24	......	......	......	1.32	1.29	1.12	......	......	......	1.56	1.51	1.32	......	......	......
107	No. 2	.95	.92	.87	1.00	.97	.92	1.12	1.08	1.03	1.18	1.14	1.08	1.05	1.02	.96	1.11	1.07	1.02	1.24	1.20	1.14	1.30	1.26	1.20
106	No. 3	1.10	1.04	.97	1.17	1.11	1.04	1.29	1.23	1.14	1.38	1.31	1.22	1.19	1.13	1.05	1.27	1.21	1.12	1.40	1.33	1.24	1.50	1.42	1.32
111	No. 4	1.13	1.10	1.01	1.21	1.17	1.08	1.34	1.29	1.19	1.42	1.37	1.27	1.23	1.19	1.10	1.31	1.27	1.17	1.45	1.40	1.29	1.54	1.49	1.38
125	No. 5	1.18	1.15	1.04	1.26	1.23	1.11	1.38	1.35	1.23	1.48	1.44	1.31	1.28	1.25	1.14	1.37	1.34	1.21	1.51	1.47	1.34	1.61	1.57	1.43
110	No. 6	1.45	1.39	1.10	1.56	1.51	1.19	1.70	1.64	1.28	1.84	1.78	1.40	1.59	1.53	1.20	1.72	1.66	1.30	1.87	1.80	1.42	2.02	1.95	1.53
108	No. 7A	1.27	1.23	1.07	1.36	1.32	1.14	1.50	1.45	1.26	1.60	1.55	1.35	1.38	1.35	1.16	1.48	1.43	1.24	1.63	1.58	1.37	1.74	1.69	1.46
116	Nos. 8A and 8B [a]	1.32	1.30	1.16	......	......	......	1.56	1.53	1.37	......	......	......	1.43	1.41	1.26	......	......	......	1.69	1.66	1.48	......	......	......
119	Nos. 8A and 8B [a]	1.18	1.15	1.03	1.26	1.23	1.10	1.39	1.35	1.22	1.48	1.44	1.30	1.26	1.23	1.10	1.34	1.31	1.18	1.48	1.44	1.30	1.58	1.54	1.39

[a] Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Economic results: Fuel charged in producer per horsepower hour (pounds).												Economic results: Total fuel used by producer plant per horsepower hour (pounds).											
		Per brake horsepower.						Per electrical horsepower.						Per brake horsepower.						Per electrical horsepower.					
		Developed at engine.			Commercially available.			Developed at switchboard.			Commercially available.			Developed at engine.			Commercially available.			Developed at switchboard.			Commercially available.		
		As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.
1	**2**	**127**	**128**	**129**	**130**	**131**	**132**	**133**	**134**	**135**	**136**	**137**	**138**	**139**	**140**	**141**	**142**	**143**	**144**	**145**	**146**	**147**	**148**	**149**	**150**
	Texas:																								
11	No. 1	2.54	1.69	1.43	2.68	1.79	1.51	2.98	1.99	1.68	3.16	2.10	1.78	2.83	1.89	1.60	3.00	2.00	1.69	3.34	2.22	1.88	3.53	2.35	1.99
18	No. 2	1.98	1.31	1.17	2.10	1.39	1.24	2.33	1.54	1.37	2.47	1.64	1.46	2.20	1.46	1.30	2.33	1.55	1.38	2.58	1.71	1.52	2.74	1.82	1.62
93	No. 3	2.17	1.47	1.28	2.29	1.55	1.35	2.55	1.73	1.50	2.70	1.83	1.59	2.33	1.58	1.38	2.47	1.67	1.46	2.75	1.86	1.62	2.90	1.97	1.71
92	No. 4	2.16	1.42	1.26	2.26	1.49	1.32	2.54	1.67	1.48	2.66	1.75	1.55	2.33	1.54	1.36	2.43	1.61	1.42	2.74	1.81	1.60	2.87	1.89	1.67
118	Utah No. 1	1.17	1.11	1.05	1.24	1.17	1.11	1.38	1.30	1.24	1.46	1.38	1.31	1.24	1.17	1.11	1.31	1.24	1.18	1.46	1.38	1.31	1.55	1.46	1.39
	Virginia:																								
77	No. 1	1.22	1.15	1.07	1.29	1.21	1.13	1.44	1.35	1.26	1.51	1.43	1.33	1.30	1.23	1.14	1.37	1.29	1.20	1.53	1.44	1.34	1.61	1.52	1.42
78	No. 2	1.11	1.09	1.02	1.18	1.15	1.09	1.31	1.28	1.20	1.39	1.36	1.28	1.17	1.15	1.08	1.25	1.22	1.14	1.38	1.35	1.27	1.47	1.43	1.35
75	No. 3	.96	.95	.90	1.03	1.01	.96	1.13	1.11	1.06	1.21	1.18	1.13	1.03	1.01	.96	1.10	1.08	1.03	1.21	1.19	1.13	1.29	1.27	1.21
74	No. 4	1.06	1.03	1.00	1.12	1.09	1.05	1.24	1.21	1.18	1.31	1.28	1.24	1.11	1.08	1.05	1.17	1.14	1.11	1.31	1.27	1.24	1.38	1.35	1.31
154	No. 5A	1.13	1.09	.89	1.17	1.13	.92	1.33	1.29	1.04	1.37	1.33	1.08	1.22	1.18	.96	1.27	1.22	.99	1.44	1.39	1.13	1.49	1.44	1.17
160	No. 6	.97	.92	.83	1.00	.95	.85	1.14	1.09	.97	1.18	1.12	1.00	1.06	1.01	.91	1.09	1.05	.93	1.25	1.19	1.07	1.29	1.23	1.10
163	Jamestown No. 1	1.02	1.01	.85	1.05	1.04	.87	1.20	1.19	1.00	1.23	1.22	1.03	1.26	1.24	1.05	1.29	1.28	1.07	1.48	1.46	1.23	1.52	1.50	1.26
	Washington:																								
90	No. 1A [a]	2.79	2.34	1.99	3.00	2.52	2.14	3.28	2.75	2.34	3.53	2.96	2.51	2.93	2.45	2.08	3.15	2.64	2.24	3.44	2.89	2.45	3.71	3.11	2.64
89	No. 1B	2.24	1.88	1.58	2.40	2.01	1.69	2.63	2.21	1.86	2.83	2.37	1.99	2.40	2.01	1.69	2.57	2.16	1.81	2.82	2.37	1.99	3.03	2.54	2.14
94	No. 1B	2.03	1.71	1.43	2.14	1.80	1.50	2.39	2.01	1.68	2.52	2.12	1.77	2.20	1.85	1.54	2.32	1.94	1.62	2.59	2.17	1.81	2.73	2.29	1.91
112	No. 2	1.15	1.11	.95	1.22	1.17	1.00	1.36	1.30	1.12	1.44	1.38	1.18	1.22	1.17	1.01	1.29	1.24	1.06	1.44	1.38	1.18	1.52	1.46	1.25
	West Virginia:																								
3	No. 1	1.22	1.20	1.13	1.29	1.27	1.19	1.43	1.41	1.33	1.51	1.49	1.40	1.36	1.34	1.26	1.43	1.41	1.33	1.60	1.57	1.48	1.69	1.66	1.56
4	No. 4	.99	.98	.89	1.05	1.03	.94	1.17	1.15	1.04	1.23	1.21	1.10	1.12	1.10	1.00	1.18	1.16	1.05	1.32	1.29	1.17	1.39	1.36	1.24
23	No. 7	1.13	1.10	1.02	1.20	1.16	1.08	1.33	1.29	1.20	1.41	1.37	1.27	1.28	1.24	1.15	1.35	1.31	1.22	1.50	1.46	1.36	1.59	1.55	1.44
19	No. 8	1.40	1.36	1.28	1.47	1.43	1.35	1.64	1.60	1.51	1.73	1.68	1.58	1.55	1.51	1.42	1.63	1.59	1.49	1.82	1.78	1.67	1.92	1.87	1.76
17A	No. 9	1.35	1.31	1.23	1.23	1.20	1.13	1.45	1.41	1.33	1.58	1.54	1.45	1.38	1.34	1.26	1.51	1.47	1.38	1.62	1.58	1.49	1.77	1.72	1.62
17B	No. 9	1.27	1.24	1.16	1.36	1.33	1.25	1.49	1.46	1.37	1.60	1.56	1.47	1.39	1.35	1.27	1.49	1.46	1.37	1.64	1.59	1.50	1.76	1.71	1.61
21	No. 9	1.07	1.04	.97	1.18	1.10	1.02	1.26	1.23	1.14	1.32	1.29	1.20	1.21	1.19	1.10	1.28	1.25	1.16	1.43	1.40	1.30	1.51	1.47	1.37

161	No. 11B....	1.65	1.64	.92	1.70	1.69	.95	1.95	1.94	1.09	2.00	1.99	1.12	......	......	......	......	......	......	......	......	......	......	......	......
8	No. 12......	1.15	1.13	1.06	1.20	1.18	1.11	1.35	1.33	1.24	1.41	1.39	1.30	1.30	1.28	1.20	1.35	1.34	1.25	1.53	1.50	1.40	1.59	1.57	1.47
56	No. 13......	.83	.80	.78	.87	.85	.82	.97	.95	.91	1.03	1.00	.96	.88	.86	.83	.93	.91	.89	1.04	1.01	.97	1.10	1.07	1.03
54	No. 14......	.87	.85	.82	.92	.89	.87	1.03	1.00	.97	1.08	1.05	1.02	.93	.90	.88	.98	.95	.92	1.10	1.06	1.03	1.15	1.12	1.08
86	No. 16A....	1.13	1.10	1.02	1.20	1.17	1.09	1.33	1.30	1.20	1.41	1.38	1.28	1.19	1.16	1.08	1.26	1.24	1.15	1.40	1.37	1.27	1.49	1.45	1.35
80	No. 18......	.97	.94	.88	1.02	1.00	.94	1.14	1.11	1.04	1.20	1.17	1.10	1.02	.99	.94	1.08	1.05	.99	1.20	1.17	1.10	1.27	1.24	1.17
82	No. 20......	1.05	1.03	.95	1.12	1.09	1.01	1.24	1.22	1.12	1.31	1.29	1.19	1.11	1.09	1.01	1.18	1.16	1.17	1.31	1.29	1.19	1.39	1.36	1.26
162	No. 24......	1.26	1.22	.87	1.32	1.28	.91	1.48	1.44	1.02	1.55	1.51	1.07	......	......	......	......	......	......	......	......	......	......	......	......
156	No. 25......	1.11	1.07	.98	1.15	1.11	1.01	1.31	1.26	1.15	1.35	1.30	1.19	1.17	1.12	1.03	1.21	1.16	1.06	1.37	1.32	1.21	1.42	1.37	1.25
164	Jamestown No. 3.....	.93	.92	.85	.96	.94	.87	1.10	1.08	1.00	1.13	1.11	1.03	1.11	1.09	1.01	1.14	1.12	1.03	1.30	1.28	1.19	1.34	1.32	1.22
165	Jamestown No. 4.....	.90	.88	.83	.92	.91	.86	1.05	1.04	.98	1.09	1.07	1.01	1.03	1.01	.96	1.06	1.05	.99	1.21	1.19	1.13	1.25	1.23	1.16
166	Jamestown No. 5.....	.89	.88	.82	.92	.90	.84	1.05	1.03	.96	1.08	1.06	.99	1.01	.99	.92	1.04	1.02	.95	1.19	1.16	1.09	1.22	1.20	1.12
167	Jamestown No. 7.....	1.02	1.00	.94	1.04	1.03	.97	1.19	1.17	1.11	1.23	1.21	1.14	1.13	1.11	1.05	1.16	1.14	1.08	1.33	1.30	1.23	1.37	1.35	1.27
168	Jamestown No. 7.....	.92	.91	.86	.95	.93	.88	1.09	1.07	1.01	1.12	1.10	1.04	1.04	1.02	.96	1.06	1.05	.99	1.22	1.20	1.13	1.25	1.23	1.16
	Wyoming:																								
16	No. 2.......	1.70	1.54	1.19	1.86	1.68	1.30	2.00	1.82	1.40	2.18	1.98	1.52	1.94	1.76	1.36	2.11	1.92	1.48	2.28	2.07	1.60	2.49	2.25	1.74
62	No. 2B.....	1.83	1.68	1.28	1.93	1.77	1.35	2.16	1.97	1.50	2.28	2.08	1.59	1.94	1.77	1.35	2.05	1.87	1.43	2.28	2.09	1.59	2.40	2.20	1.68
69	No. 3.......	1.63	1.42	1.17	1.74	1.52	1.25	1.92	1.67	1.37	2.05	1.78	1.47	1.74	1.51	1.24	1.86	1.62	1.33	2.04	1.78	1.46	2.19	1.90	1.57
123	No. 4.......	1.76	1.56	1.43	1.87	1.66	1.52	2.07	1.83	1.68	2.20	1.95	1.79	1.91	1.69	1.55	2.02	1.80	1.65	2.24	1.99	1.83	2.38	2.11	1.94
114	No. 5.......	1.36	1.21	1.16	1.46	1.29	1.24	1.60	1.42	1.36	1.72	1.52	1.46	......	......	......	......	......	......	......	......	......	......	......	......
124	No. 6.......	1.86	1.52	1.47	1.97	1.61	1.53	2.19	1.79	1.73	2.32	1.90	1.83	2.02	1.65	1.59	2.14	1.75	1.69	2.38	1.94	1.88	2.52	2.06	1.99
	Miscellaneous:																								
151	Coke.......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
50	Coke breeze	1.73	1.50	1.25	1.83	1.58	1.32	2.04	1.76	1.47	2.16	1.87	1.55	......	......	......	......	......	......	......	......	......	......	......	......
153	Refuse......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

a Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Auxiliary power used by producer plant.						Efficiency (per cent).					Pounds of tar per ton of fuel.		Page on which notes appear.
		To drive tar extractor. (E. H. P.)	Used by producer (pounds).					Of conversion and cleaning gas.	Of producer plant.	Thermal, based on stated horsepower and gas horsepower.		Of entire plant, based on E. H. P., commercially available and fuel consumed.	Water extracted.	Water not extracted.	
			Steam.		Fuel equivalent of steam per hour.										
			Total.	Per hour.	As fired.	Dry.	Combustible.			Brake.	Electrical.				
1	2	123	151	152	153	154	155	156	157	159	160	164	165	166	167
	Alabama:														
2	No. 2	8.0	9,200	214	30.9	29.7	26.8	64.8	58.6	23.9	20.3	11.2	....	....	103
109	No. 4	11.4	3,770	157	21.3	20.7	18.0	....	....	20.9	17.8	13.6	536	....	103–104
155	No. 6	6.1	6,600	132	16.6	16.2	15.1	71.5	66.4	24.5	20.8	13.5	....	....	104
	Argentina:														
141	Argentina (special)	....	....	....	....	....	....	....	....	....	....	....	....	....	104–105
169	Jamestown No. 8	....	....	....	....	....	....	....	....	....	....	....	....	....	255
	Arkansas:														
96	No. 7A	11.8	8,500	170	22.5	21.6	18.8	72.2	65.8	17.3	14.7	8.9	....	130	105
95	No. 8	9.1	5,070	195	29.2	28.4	23.8	64.2	58.6	20.1	17.0	9.5	....	52	105–106
91	No. 10	10.1	3,490	194	64.9	39.3	33.0	51.9	45.1	25.6	21.7	9.1	....	289	106
44	Brazil: No. 1	13.6	3,410	142	31.7	28.2	20.8	69.6	62.8	20.0	17.0	9.8	....	225	106–107
	California:														
32	No. 1	12.2	4,920	117	29.3	24.2	19.7	59.6	56.3	21.6	18.3	9.8	....	....	107
33	No. 1[a]	....	....	....	....	....	....	....	....	....	....	....	....	....	108
34	No. 1[a]	8.6	5,260	219	54.8	45.3	36.7	55.4	50.2	23.8	20.3	....	....	....	108
15	Colorado: No. 1	13.8	9,240	308	64.0	51.0	47.3	64.2	54.3	....	....	11.3	....	....	108
117	Florida: No. 1	8.7	7,600	152	35.6	28.1	26.3	65.2	61.2	19.8	16.9	9.9	157	....	109
	Illinois:														
6	No. 3	7.1	6,690	223	36.0	33.4	29.9	64.0	57.8	22.2	18.8	10.5	....	....	109
9	No. 4	9.3	7,800	260	48.2	42.2	37.8	69.2	60.3	21.8	18.6	10.8	....	....	109
35	No. 6B	11.4	7,920	132	28.2	24.9	20.4	69.5	64.4	22.5	19.1	11.7	....	....	109–110
26	No. 7A	8.3	1,770	156	34.8	30.4	22.9	....	....	21.9	18.6	....	....	....	110
27	No. 7B	8.9	4,920	164	37.1	32.7	26.2	59.9	55.1	22.6	19.2	10.1	....	....	110
38	No. 7C	11.7	5,910	179	31.2	28.0	22.1	50.1	46.7	22.0	18.7	8.2	....	....	110–111
29	No. 8	10.1	5,795	138	29.3	25.5	22.1	67.0	62.0	22.8	19.3	11.5	....	....	111
28	No. 9B	9.9	7,920	132	23.1	20.3	17.7	63.6	59.8	22.9	19.4	11.1	....	....	111
31	No. 10	12.3	5,100	102	17.5	16.0	14.1	74.1	69.4	22.8	19.4	12.8	....	....	111–112

30	No. 11A	13.8	4,450	84	14.3	13.3	11.7	83.8	78.9	21.4	18.2	13.6	....	....	112
36	No. 11C [b]	11.5	3,850	160	26.6	23.2	20.1	....	....	22.2	18.9	....	....	....	112
42	No. 11D [b]	12.7	7,550	151	25.1	22.9	21.0	83.6	75.1	23.1	19.7	14.0	....	....	112
48	No. 11D [b]	12.0	8,650	173	28.7	26.4	24.3	....	....	....	....	14.0	....	305	113
41	No. 13	11.1	7,750	155	23.6	21.5	19.1	63.9	59.4	24.6	20.9	11.9	....	....	113
37	No. 14	11.4	6,550	131	23.0	20.1	17.2	72.7	67.5	23.0	19.6	12.6	....	....	113-114
39	No. 15	....	....	....	....	....	....	....	....	....	....	....	....	....	114
40	No. 15	12.1	6,300	126	21.2	19.2	16.4	73.5	68.7	22.0	18.7	12.1	....	....	114
43	No. 16	10.6	6,850	137	19.1	17.7	15.7	65.7	61.9	22.3	18.9	11.2	....	210	114
45	No. 18	12.4	8,550	171	26.3	22.8	20.2	73.6	67.6	23.0	19.5	12.5	....	241	114-115
55	No. 19B	11.0	5,500	110	15.8	14.3	12.8	86.3	81.0	21.1	17.9	13.8	....	210	115
128	No. 19C	9.8	8,800	176	26.4	23.8	21.1	71.2	64.8	17.9	15.2	9.2	....	....	115
105	No. 21	9.5	83,176	148	25.7	21.9	19.0	72.7	67.6	20.2	17.2	11.1	144	....	116-119
102	No. 22A	12.1	5,920	126	21.3	18.9	16.1	73.9	69.1	21.4	18.2	11.9	....	....	119
98	No. 23A	10.1	5,550	111	19.1	16.9	14.6	68.4	64.6	22.6	19.2	11.8	....	396	119-120
100	No. 23B [b]	8.9	8,400	168	29.9	25.5	22.8	68.2	62.4	21.4	18.2	10.8	97	....	120
103	No. 24B	9.6	5,500	110	18.8	16.7	14.7	78.7	73.4	23.8	20.2	14.2	....	....	121
104	No. 25	10.4	4,900	98	17.7	15.7	13.3	71.2	67.0	24.6	20.9	13.4	....	....	121
126	No. 26	11.0	7,550	151	27.4	23.7	19.4	80.4	73.5	20.2	17.2	11.9	....	....	121
127	No. 27	11.4	7,400	148	26.4	23.4	19.8	61.5	56.4	18.1	15.4	7.9	....	....	122
139	No. 29B	8.7	7,700	154	25.3	22.2	19.0	....	....	....	....	11.9	....	....	122
157	No. 30 [b]	7.8	5,300	106	15.5	14.7	13.2	61.8	58.6	24.4	20.8	11.8	....	....	123
	Indiana:														
14	No. 1	11.6	6,970	235	40.1	35.5	31.5	59.3	53.5	22.2	18.8	9.6	....	....	123
13A	No. 2	9.7	5,313	253	41.6	38.0	34.0	57.0	50.4	22.5	19.1	9.1	....	....	123-124
13B	No. 2	9.6	1,770	253	41.6	38.0	34.0	78.3	68.4	21.7	18.4	12.2	....	....	123-124
53	No. 3 [b]	11.3	6,600	132	21.5	19.0	17.2	62.5	58.5	22.7	19.3	10.7	....	142	124
46	No. 5	12.5	6,090	203	32.5	29.2	25.1	56.5	51.9	24.2	20.5	10.0	....	325	124-125
47	No. 5	13.8	6,100	122	19.4	17.3	15.3	75.0	69.6	24.6	20.9	13.7	....	213	125-126
49	No. 6	10.7	9,550	191	30.3	27.0	23.2	....	....	....	....	11.1	....	162	126
51	No. 7A	10.0	7,020	156	23.0	21.2	18.8	70.9	65.5	23.4	19.9	12.4	....	293	127
57	No. 8	10.5	5,350	107	16.7	15.1	13.2	73.9	69.6	22.8	19.3	12.8	....	238	127
52	No. 9A	9.6	5,040	112	17.4	15.2	13.4	70.9	68.5	21.4	18.2	11.7	....	287	127-129
61	No. 11	10.9	7,200	180	28.0	24.3	22.0	69.5	63.5	23.4	19.8	12.0	....	314	129
99	No. 12	9.3	6,100	122	20.4	18.3	15.7	69.8	65.5	21.8	18.5	11.6	....	....	129
132	No. 13	8.8	8,950	179	27.5	24.4	20.5	67.2	61.3	21.4	18.2	10.6	....	....	129-131
138	No. 13	8.1	3,696	154	23.7	21.2	18.6	....	....	....	....	13.3	....	....	131
131	No. 14	9.6	6,100	122	19.4	17.8	15.1	69.5	65.1	22.7	19.3	12.0	....	....	131-132
134	No. 15	9.7	6,700	134	21.0	18.6	16.7	73.9	68.5	22.6	19.2	12.5	....	....	132
137	No. 15	9.8	6,900	138	21.6	19.1	17.2	71.2	65.7	24.9	21.2	13.3	....	....	132
130	No. 16	9.8	7,700	154	23.8	22.0	19.1	64.2	59.5	22.2	18.9	10.6	....	....	132-133
133	No. 18B	9.4	5,255	146	21.8	19.4	17.9	71.5	66.1	23.5	20.0	12.7	....	....	133-134
135	No. 18B	9.4	8,200	164	24.1	21.2	19.6	64.8	60.0	23.3	19.8	11.3	....	....	134
	Indian Territory:														
1	No. 1	8.0	6,640	214	31.7	30.0	27.3	64.0	58.6	21.1	17.9	10.0	....	....	134
29	No. 4	11.5	4,645	205	34.5	31.4	25.8	....	....	23.7	20.1	14.8	....	....	134-135
22	Iowa: No. 2	10.9	3,065	230	45.9	38.2	28.7	....	....	21.0	17.9	13.3	....	....	135

[a] Mixed with 50 per cent of "front-end" cinders from locomotives in test 33 and with 33⅓ per cent of the same cinders in test 34.

[b] Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Auxiliary power used by producer plant.						Efficiency (per cent).					Pounds of tar per ton of fuel.		Page on which notes appear.
		To drive tar extractor. (E. H. P.)	Used by producer (pounds).					Of conversion and cleaning gas.	Of producer plant.	Thermal, based on stated horsepower and gas horsepower.		Of entire plant, based on E. H. P., commercially available and fuel consumed.	Water extracted.	Water not extracted.	
			Steam.		Fuel equivalent of steam per hour.										
			Total.	Per hour.	As fired.	Dry.	Combustible.			Brake.	Electrical.				
1	**2**	**123**	**151**	**152**	**153**	**154**	**155**	**156**	**157**	**159**	**160**	**164**	**165**	**166**	**167**
	Kansas:														
24	No. 5	8.0	2,795	215	30.6	29.3	25.9	78.2	70.9	19.4	16.5	11.3	....	....	135
25	No. 5	10.2	7,800	260	37.0	35.4	31.6	65.6	57.8	25.4	21.6	11.9	....	....	135
101	No. 6	8.9	1,668	122	20.2	18.2	15.6	72.1	67.6	21.9	18.6	12.1	....	....	135
	Kentucky:														
79	No. 1B	10.7	6,150	123	15.7	15.3	14.8	....	....	....	....	12.0	....	488	135–136
12	No. 3	10.7	7,740	258	40.8	37.9	34.2	65.0	58.3	20.3	17.3	9.6	....	....	136
81	No. 5	11.8	6,400	128	16.4	15.7	15.1	77.5	72.3	21.3	18.1	12.4	....	602	136
85	No. 6	11.9	5,400	108	13.6	13.0	12.6	82.0	77.2	21.1	17.9	13.1	....	588	136–137
84	No. 7	11.2	5,700	114	16.8	15.4	13.8	70.6	66.4	22.7	19.2	12.1	....	255	137
97	Massachusetts: No. 1	8.9	....	....	....	....	....	....	....	....	....	....	....	240	137–141
	Missouri:														
7A	No. 2	11.3	....	....	57.4	50.8	42.3	52.0	47.0	20.8	17.7	7.9	....	....	141
7B	No. 2	12.9	....	....	38.0	33.6	28.0	74.2	66.4	22.0	18.7	11.7	....	....	141
	Montana:														
5A	No. 1	8.5	....	....	50.3	44.6	39.2	55.1	49.5	22.5	19.1	9.1	....	....	141
5B	No. 1	8.0	....	....	39.3	34.8	30.6	54.6	53.8	18.0	15.3	7.1	....	....	141
149	No. 2	7.5	8,800	220	38.3	35.0	29.1	64.6	58.5	21.7	18.4	10.4	....	....	141–170
150	No. 3	7.0	6,075	124	21.6	19.7	16.8	73.3	68.4	23.4	19.9	13.2	338	....	170
	New Mexico:														
121	No. 3A	11.1	6,400	128	18.7	18.0	14.3	....	....	22.6	19.2	....	343	....	170
122	No. 4A	11.9	8,600	172	25.3	24.7	21.3	66.0	59.7	....	....	12.6	....	....	170
120	No. 5	11.2	6,390	142	20.3	19.9	16.8	81.5	75.3	20.9	17.7	12.7	501	....	170
	North Dakota:														
68	No. 1B	14.4	5,000	102	29.0	19.5	16.2	67.1	63.0	24.0	20.3	12.0	....	97	170
10	No. 2	9.1	4,500	150	50.0	30.0	26.8	69.6	62.4	18.5	15.7	9.2	....	....	170–174

72	No. 2B	9.7	5,650	113	32.1	20.5	18.9	......	......	......	......	11.7	......	91	174
152	No. 2B	6.8	1,608	134	38.1	23.3	21.2	70.1	65.1	23.7	20.1	12.7	......	......	174
67	No. 3	10.4	4,900	98	27.8	17.9	16.1	57.0	54.0	23.3	19.8	10.2	......	66	174
	Ohio:														
64	No. 3 [a]	12.9	6,400	128	18.4	16.9	15.5	76.8	71.6	22.5	19.1	12.9	......	421	174
60	No. 4	10.1	3,250	130	18.4	17.4	16.0	80.0	74.0	22.9	19.5	13.7	......	476	174
58	No. 5	11.9	6,400	128	17.0	16.3	15.3	82.3	76.1	23.2	19.7	14.2	......	287	174
76	No. 6	9.3	6,250	125	17.2	16.6	15.1	......	......	21.5	18.3	14.3	......	481	174-180
87	No. 7	10.1	5,040	123	17.5	16.6	15.2	67.1	63.1	22.0	18.7	11.3	......	330	180
83	No. 8	13.5	4,150	83	12.1	11.1	9.6	83.2	79.2	21.3	18.1	13.5	......	423	180
73	No. 9A	10.1	6,850	137	21.7	20.1	18.3	......	......	......	......	13.5	......	431	180
142	No. 10	7.6	5,800	116	15.7	15.1	13.7	81.4	76.1	22.6	19.2	14.2	......	......	180
145	No. 11	8.4	7,000	140	19.8	19.1	16.6	76.0	70.5	23.1	19.7	13.3	......	......	180
146	No. 12	8.9	5,505	162	22.3	21.6	19.4	66.0	61.4	22.3	18.9	11.1	......	......	180
147	No. 12	8.0	8,100	126	22.3	21.4	19.0	69.2	63.9	23.5	20.0	12.3	......	......	180-184
	Pennsylvania:														
65	No. 4	9.5	5,200	104	12.6	12.4	11.0	71.7	67.9	22.9	19.4	12.6	......	379	184
59	No. 5B	12.9	6,150	123	16.4	15.8	14.5	74.7	69.4	24.7	21.0	13.7	......	512	184
66	No. 6 [a]	14.1	6,535	139	18.0	17.6	16.2	58.4	54.4	......	......	11.2	......	367	184
70	No. 6A and 6B	10.7	4,950	99	13.3	12.9	11.3	82.2	77.0	24.2	20.6	15.0	......	498	184
88	No. 7	10.6	6,600	132	17.5	16.9	14.7	66.8	62.2	21.6	18.3	10.8	......	224	184
63	No. 8	10.5	7,600	152	18.0	17.6	16.3	81.1	74.4	21.8	18.5	13.1	......	141	184
71	No. 10	9.5	5,250	105	12.6	12.2	11.2	74.4	70.2	23.6	20.1	13.8	......	379	184-190
129	No. 11	10.8	8,100	162	21.0	20.6	19.1	76.1	69.5	20.0	17.0	11.2	......	......	190
143	No. 12	7.9	4,760	170	22.3	21.8	19.8	86.6	78.0	22.8	19.4	14.6	......	......	190-192
136	No. 13	8.4	8,100	162	22.5	22.0	19.0	77.2	70.4	23.2	19.7	13.4	......	......	192
140	No. 13	8.3	7,700	154	20.8	20.5	18.0	82.7	75.5	23.0	19.5	14.2	......	......	192-195
144	No. 15	7.5	4,510	188	25.8	25.1	22.4	80.0	71.8	22.0	18.7	13.0	......	......	195
148	No. 16	8.5	9,100	182	24.0	22.7	20.8	......	......	23.4	19.9	......	......	......	195
158	No. 17	7.3	5.800	116	15.9	15.2	13.2	70.8	66.4	23.6	20.1	12.9	......	......	195-197
159	No. 22	7.5	5,400	108	14.5	13.9	12.4	80.2	75.1	23.7	20.2	14.6	......	......	197
113	Rhode Island: No. 1	......	......	......	......	......	......	......	......	......	......	......	......	......	199
	Tennessee:														
115	No. 1	......	6,000	120	16.9	16.4	14.4	......	......	......	......	......	203	......	199-202
107	No. 2	10.4	9,250	185	23.9	23.1	22.0	......	......	20.6	17.5	14.1	......	......	202
106	No. 3	13.0	8,150	163	22.3	21.2	19.7	83.1	75.9	21.3	18.1	12.9	......	......	202
111	No. 4	10.9	7,800	156	20.9	20.2	18.6	82.6	75.5	20.2	17.2	12.3	322	......	202
125	No. 5	12.0	8.700	174	23.2	22.7	20.6	74.6	67.9	21.6	18.4	11.8	......	......	202
110	No. 6	11.9	5,730	191	26.2	25.2	19.9	75.0	67.6	20.3	17.2	10.8	476	......	202
108	No. 7A	12.1	9,250	185	25.6	24.9	21.5	77.8	70.9	20.4	17.4	11.6	195	......	204
116	Nos. 8A and 8B [a]	......	6,600	132	18.9	18.6	16.6	......	......	......	......	......	383	......	204
119	Nos. 8A and 8B [a]	12.3	3,070	128	18.3	17.9	16.1	78.7	73.2	20.4	17.4	12.0	355	......	207
	Texas:														
11	No. 1	11.0	......	......	70.0	46.5	39.3	65.3	57.9	21.2	18.0	9.9	......	......	207-209
18	No. 2	11.6	5,020	260	51.5	34.1	30.4	72.7	65.0	24.1	20.5	12.6	......	......	209
93	No. 3	10.9	7,500	150	39.4	26.7	23.2	72.2	66.5	21.4	18.2	11.5	......	206	209-210
92	No. 4	8.5	7,400	148	38.8	25.6	22.7	......	......	......	......	11.9	......	191	210

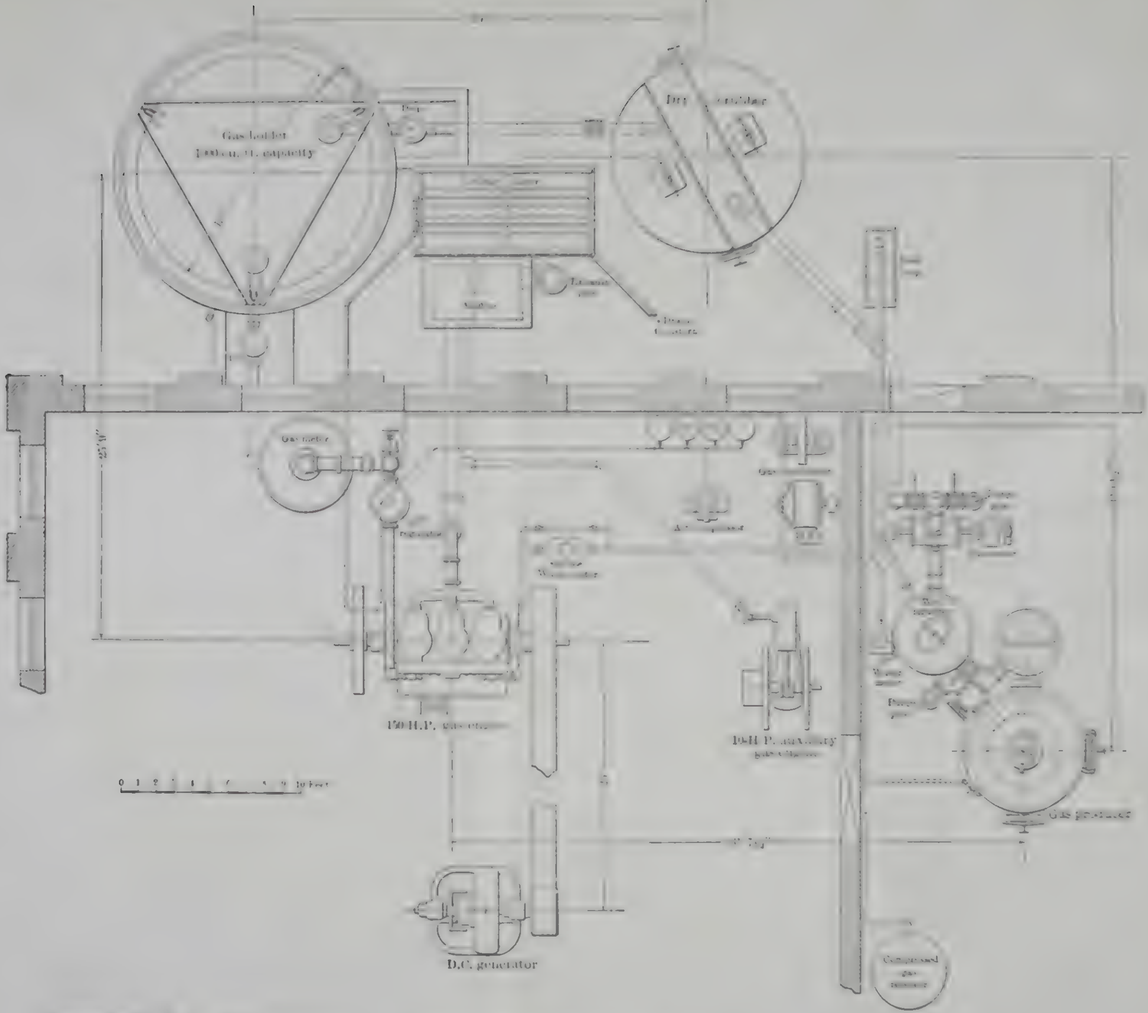
[a] Washed.

Results of producer-gas tests made at St. Louis and Norfolk—Continued.

Test No.	Designation of fuel.	Auxiliary power used by producer plant.						Efficiency (per cent).					Pounds of tar per ton of fuel.		Page on which notes appear.
		To drive tar extractor. (E. H. P.)	Used by producer (pounds).					Of conversion and cleaning gas.	Of producer plant.	Thermal, based on stated horsepower and gas horsepower.		Of entire plant, based on E. H. P., commercially available and fuel consumed.	Water extracted.	Water not extracted.	
			Steam.		Fuel equivalent of steam per hour.										
			Total.	Per hour.	As fired.	Dry.	Combustible.			Brake.	Electrical.				
1	**2**	**123**	**151**	**152**	**153**	**154**	**155**	**156**	**157**	**159**	**160**	**164**	**165**	**166**	**167**
118	Utah: No. 1...	11.0	6,300	126	17.0	16.0	15.2	76.9	72.0	21.3	18.1	12.4	95	....	210
	Virginia:														
77	No. 1..	9.9	7,250	145	18.2	17.2	16.0	72.8	67.9	21.5	18.3	11.9	...	477	211
78	No. 2..	11.5	5,600	112	13.7	13.3	12.5	...	...	...	...	12.3	...	463	211
75	No. 3.	11.6	6,400	128	15.7	15.5	14.7	80.7	74.7	22.3	19.0	13.5	...	475	211
74	No. 4.	10.3	5,100	102	13.0	12.7	12.3	...	...	...	...	12.7	...	747	211
154	No. 5A...	6.7	4,140	138	22.3	21.5	17.5	74.5	68.4	24.9	21.2	14.0	...	...	212-213
160	No. 6.	5.8	7,300	146	20.8	19.9	17.8	81.0	73.6	24.3	20.7	14.8	...	...	213
163	Jamestown No. 1..	5.3	2,190	274	56.3	55.6	46.9	89.4	72.4	22.1	18.8	13.3	...	...	228-229
	Washington:														
90	No. 1A[a].	10.2	4,960	124	23.8	19.9	16.9	...	...	18.9	16.0	7.0		257	213-214
89	No. 1B....	10.6	6,160	154	29.5	24.7	20.8	64.4	59.7	18.2	15.5	8.7	...	260	214
94	No. 1B...	10.0	2,770	198	38.0	31.9	26.6	57.1	51.9	22.8	19.3	9.7		118	214
112	No. 2.	10.7	3,960	113	15.9	15.2	13.0	80.1	75.0	22.5	19.2	13.7	624	...	214
	West Virginia:														
3	No. 1..	10.3	5,900	246	33.1	32.6	30.6	64.3	57.4	22.9	19.5	10.7	...	...	215
4	No. 4......	10.5	2,119	236	29.8	29.2	26.5	82.0	72.0	22.5	19.1	13.2	...	...	216
23	No. 7...	11.4	6,200	276	34.3	33.3	31.0	...	...	17.7	15.1	11.2	...	...	216
19	No. 8.	9.6	5,775	275	36.1	35.1	33.0	62.2	55.8	20.7	17.6	9.4	...	...	216-217
17A	No. 9......	14.2	1,253	236	28.9	28.1	26.5	68.6	60.8	21.2	18.0	10.1	...	...	217
17B	No. 9...	14.1	1,253	236	28.9	28.1	26.5	55.8	50.6	...	...	10.2	...	...	217
21	No. 9.	10.3	6,795	283	31.8	31.0	31.6	78.2	68.2	21.5	18.2	11.9	...	...	217
161	No. 11B...	5.5	6,700	134	...	...	...	71.1	...	24.3	20.6	...	...	...	217-219
8	No. 12..	8.5	8,550	285	34.9	31.4	32.2	68.5	60.4	22.1	18.8	10.9	...	...	219
56	No. 13..	10.6	5,650	113	13.0	12.6	12.2	...	...	22.0	18.7	...	...	451	219
54	No. 14.	9.4	5,500	117	13.3	12.9	12.5	...	...	22.0	18.7	...	...	478	221
86	No. 16A.....	11.8	5,950	119	14.5	14.2	13.2	72.2	67.9	22.6	19.2	12.3	...	566	221

80	No. 18	11.1	5,500	110	13.0	12.7	11.9	......	......	......	......	14.1	......	562	221
82	No. 20	11.1	5,700	114	14.3	14.0	13.0	83.4	78.1	20.8	17.7	13.1	......	507	222
162	No. 24	6.9	8.400	168	......	......	......	77.6	......	24.8	21.1	......	......	......	222
156	No. 25	7.1	4.850	97	13.0	12.5	11.4	70.3	66.6	24.6	20.9	13.5	......	......	223
164	Jamestown No. 3	5.3	36,106	251	41.2	40.6	37.5	80.8	67.8	23.5	19.9	13.2	......	136	229–236
165	Jamestown No. 4	6.2	53,669	224	32.0	31.5	29.8	82.3	71.3	23.6	20.1	13.9	......	118	236–242
166	Jamestown No. 5	5.3	36,853	173	27.0	26.5	24.8	87.7	77.4	22.7	19.3	14.6	......	231	242–248
167	Jamestown No. 7	5.7	7,950	181	26.1	25.7	24.3	80.4	72.1	21.3	18.1	12.7	......	165	248–250
168	Jamestown No. 7	5.7	36,276	151	26.2	25.8	24.4	85.7	76.1	21.9	18.7	13.9	......	181	250-255
	Wyoming:														
16	No. 2	16.4	7,470	249	56.5	51.2	39.5	58.0	50.0	......	......	10.6	......	......	223–224
62	No. 2B	10.0	5,685	116	24.0	22.0	16.7	62.0	58.2	22.7	19.3	10.7	......	304	224
69	No. 3	12.7	5,875	125	24.4	21.2	17.5	76.6	71.3	21.9	18.6	12.5	......	500	224
123	No. 4	11.5	9,100	182	34.2	30.4	27.9	......	......	......	......	10.0	92	......	224–225
114	No. 5	12.6	7,600	152	......	......	......	74.0	......	21.5	18.3	......	256	......	225
124	No. 6	11.4	8,800	176	36.9	30.2	29.1	......	......	......	......	9.7	110	......	225
	Miscellaneous:														
151	Coke	......	7,544	184	......	......	......	......	......	......	......	......	......	......	226
50	Coke breeze	10.7	4,260	142	......	......	......	69.2	......	20.9	17.7	......	......	161	226–227
153	Refuse	......	......	......	......	......	......	......	......	......	......	......	......	......	227

a Washed.



87080°—Bull. 13—11. (To face page 315).

FIGURE 214.—Plan of producer-gas plant at Pittsburg

PART III.

REPORT OF INVESTIGATIONS AT PITTSBURG.

By R. H. Fernald and C. D. Smith.

INTRODUCTION.

Investigations at St. Louis and Norfolk demonstrated the possibilities of utilizing a wide range of fuels in producer-gas power plants. Among the fuels tested at St. Louis were a number containing over 20 per cent of ash. In one case the ash ran as high as 44 per cent. This fact, together with the general interest in the conservation of fuel resources, made it desirable to carry on tests upon various types of low-grade fuel and refuse material. Accordingly, at Pittsburg the investigations were directed along this line, tests being made on high-ash fuels, roof slabs, and washery refuse. Other types of fuels were also tested, such as lignite, peat, and Rhode Island graphitic anthracite. The character of the fuels selected was such that no attempt was made to determine the highest possible efficiency with which each might be used, but the tests were conducted simply to demonstrate the possibility of successfully utilizing such materials.

Observations and records were, of course, made at all times, and the figures secured are presented in the following pages; but in examining these the main purpose of the investigations and the methods pursued in conducting the tests should not be forgotten.

PERSONNEL.

The tests, under the general direction of R. H. Fernald, engineer in charge of producer-gas tests, and the personal supervision of D. T. Randall (until April, 1909) and C. D. Smith (April, 1909, to July 1, 1910), were made by the following men: C. D. Smith, F. E. Woodman, D. F. Smith, W. J. Harris, jr., W. A. Wicks, N. H. Snyder, E. J. Billings, A. J. Hazlewood, E. W. Miller, L. R. Ebert, G. A. Burrill, and Lauson Stone.

EQUIPMENT.

The equipment consisted of a complete gas-producer outfit rated at 150 horsepower, a three-cylinder vertical gas engine of equal capacity, a 175-kilowatt direct-current generator, and such auxiliary apparatus as was necessary for the operation of the plant. Figure 214 shows a plan of the plant, together with its general arrangement and principal dimensions. Figure 215 shows an elevation.

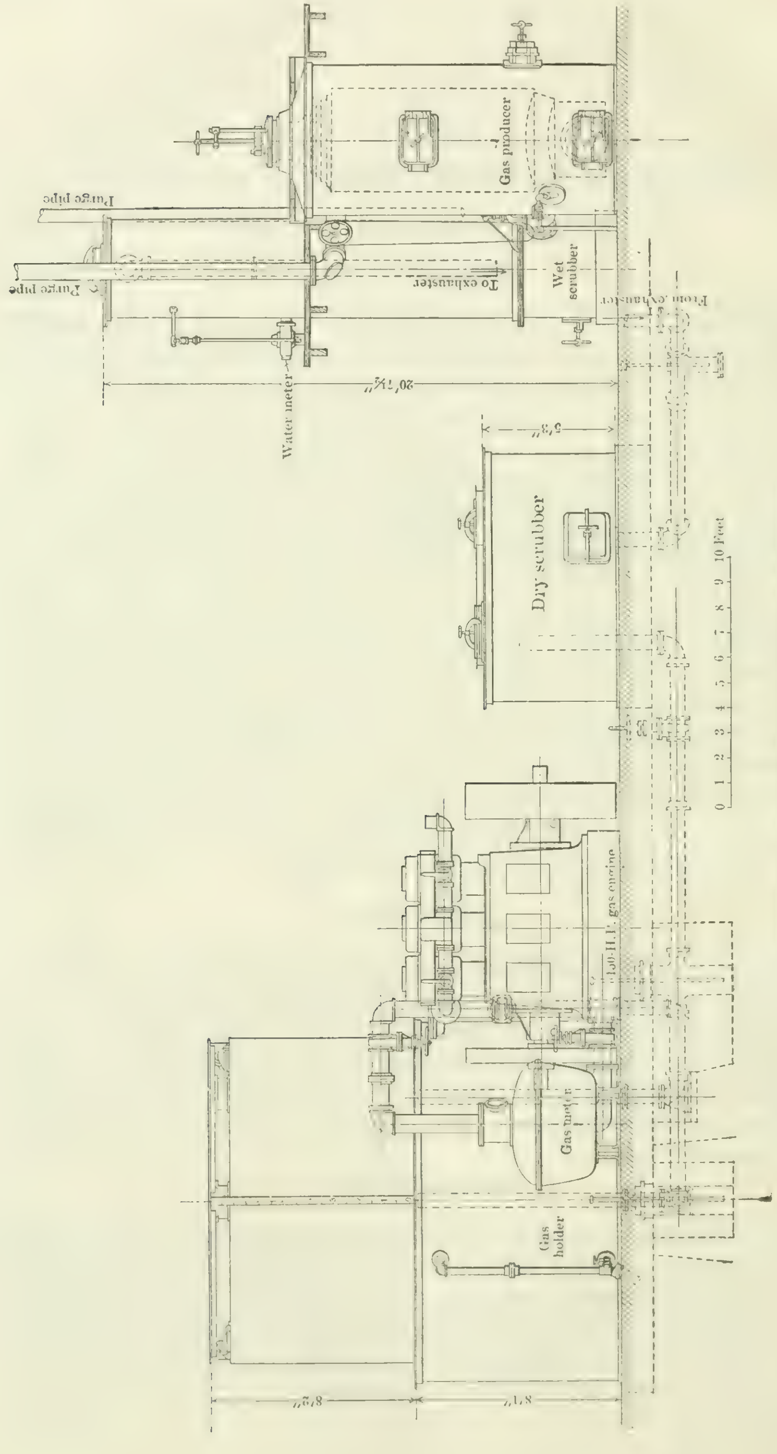


FIGURE 215.—Elevation of producer-gas plant at Pittsburg.

The producer was a single-generator unit of the down-draft type, consisting of a single cylindrical shell 6 feet in diameter and 12.5 feet high. This shell had a fire-brick lining about 1 foot in thickness, thus making the internal diameter of the gas generator approximately 4 feet. Near the bottom of the generator was a fire-brick grate upon which the fuel bed rested, and down through which the gas was drawn during the operation of the plant. Plate VI (p. 32) gives a section of this type of plant, and Plate X, *A* shows the producer-room installation at Pittsburg.

To facilitate the removal of ash and refuse, cleaning doors were provided, one opening into the ash pit or space beneath the grate, another just above the grate, and a third about 5 feet above the grate. The upper one, however, was used very little, and after three or four tests it was bricked up to prevent excessive heating of the producer shell. All fuel was charged into the producer from the top through a circular opening fitted with a swinging cover. Inasmuch as the draft was always downward, the cover could be left open for a considerable period for charging fuel or for an inspection of the fuel bed without interfering with the action of the producer. A purge pipe was provided, which served as a vent for the producer during shutdowns. This vent, or purge pipe, was closed, however, whenever the plant was in operation. Plate X, *B* is an illustration of the charging floor and producer top.

From the base of the producer the gases passed to an economizer, in which the heat of the gas was used to form the steam and to preheat the air used in the operation of the producer. The economizer was of the vertical-return tubular type. The hot gases from the producer entered the base of the economizer and passed upward through a large central tube to a header, from which several smaller return flues conducted the gases downward to an outlet casting at the base. Near the top of this large central tube was a small reservoir or basin from which water flowed down over the hot central tube, and was thus evaporated. Air entering at the base of the economizer shell passed upward around the hot tubes, picked up the water vapor, and entered highly heated at the top of the producer. Water was supplied to the economizer from a graduated tank through a constant-head device so arranged that the water at the outlet orifice was automatically maintained at approximately the same head regardless of the quantity in the supply tank, thus insuring a nearly constant flow of water to the economizer. This graduated tank and constant-head device are shown in detail in figure 216.

The gas then passed from the economizer to a wet scrubber 4 feet in diameter and 20 feet high, entering at the base through a water seal and passing upward through several layers of coke, upon which there was a continual spray of water. Above the coke and water spray in the upper part of the wet scrubber was a layer of excelsior, which served to dry the gas to a considerable extent as it passed through to the outlet pipe. The wet scrubber was well provided with manholes, by means of which its interior could be easily inspected from time to time and through which the dirty coke could be removed and fresh coke inserted when necessary. The water outlet from the base of the scrubber was connected to an open dust trap, as shown in figure 216. All of the dust, dirt, lampblack, etc., washed from the gas in the wet scrubber collected in this trap, and from time to time during a test the quantity and character of the impurities thus collected could be easily observed.

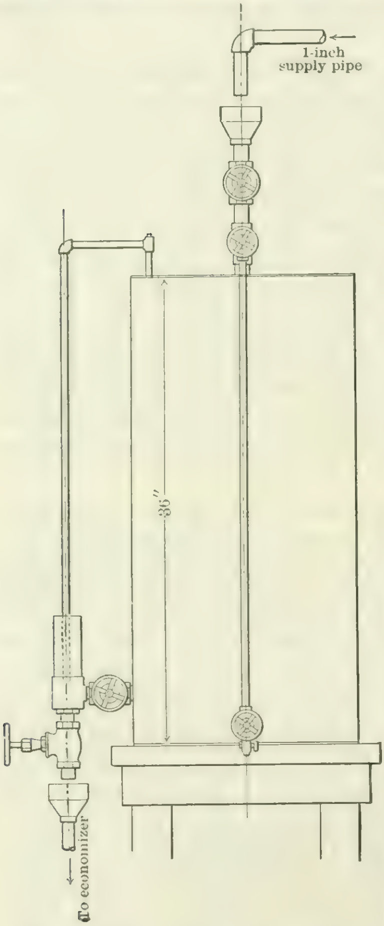
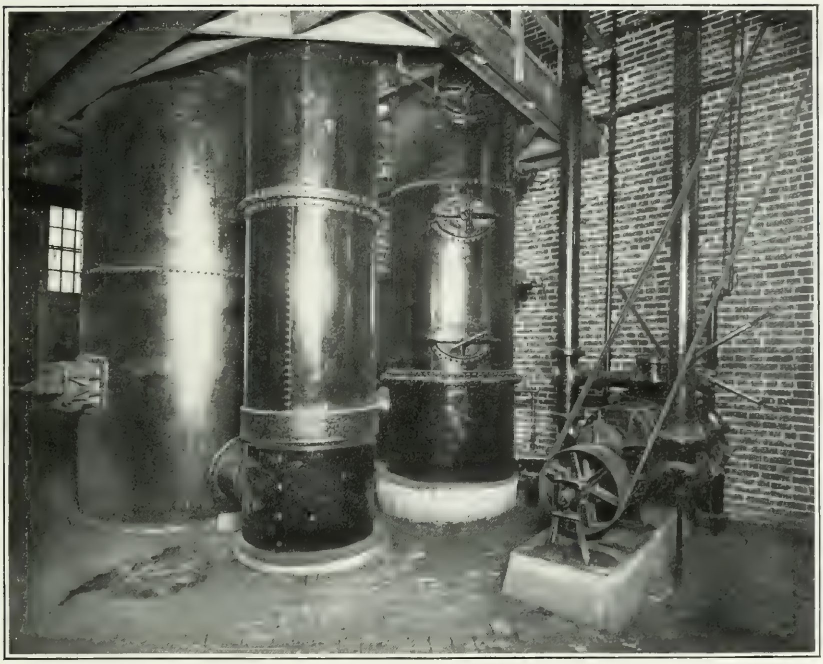
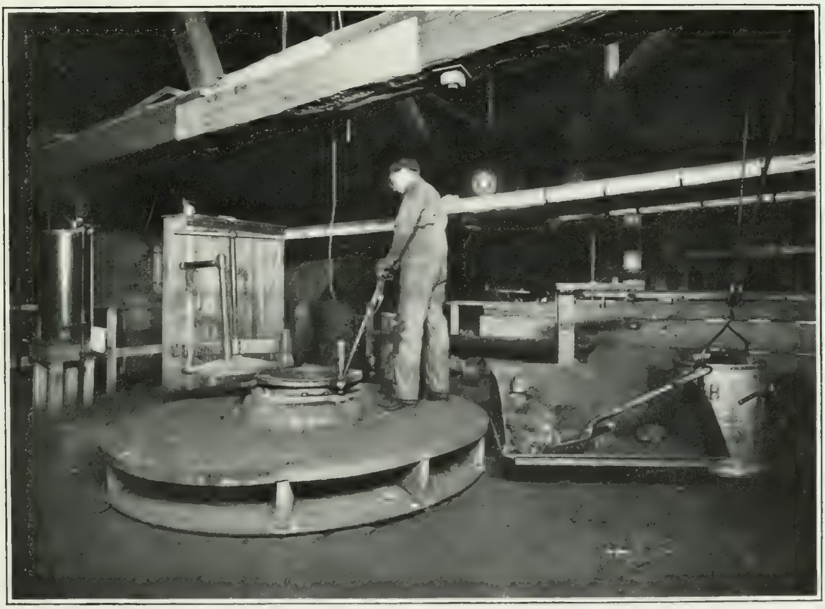


FIGURE 216.—Constant-head device.

From the top of the wet scrubber the gas passed downward through a vertical pipe to the exhauster, as illustrated in figure 216 and in Plate VI (p. 32). This exhauster was of the cycloidal interlocking impeller type; it was belt driven and had a capacity of about 3 cubic feet per revolution. The speed of the exhauster was practically constant, but the volume of gas delivered was automatically regulated by the gas holder, which controlled a by-pass valve connected with the exhauster. Whenever the gas holder was above its normal position as a result of excess gas, the by-pass valve opened and a portion of the gas from the outlet side of the exhauster passed back to the inlet side, thus decreasing the quantity of gas delivered to the gas holder, and consequently, by the same amount, the quantity of gas drawn from the producer. Whenever the gas holder fell below its normal position, the by-pass valve closed and the maximum output of the exhauster was delivered to the gas holder. The action of the exhauster created a suction throughout the system from the producer to the inlet side of the exhauster, the amount of suction at the exhauster inlet varying from about 2 inches to 60 inches of water, depending upon the resistance of the economizer and wet scrubber and upon the condition of



A. GAS PRODUCER, SCRUBBER AND ECONOMIZER AT PITTSBURG PRODUCER-GAS PLANT.



B. CHARGING FLOOR OF PITTSBURG PRODUCER-GAS PLANT.

the fuel bed in the producer. From the outlet side of the exhauster to the engine the gas was under a pressure of about 5 inches of water.

From the exhauster the gas entered the dry scrubber, a tank 10 feet in diameter and 5 feet high, which was filled from half to two-thirds full of excelsior, through which the gas passed and received a further drying and scrubbing. The gas then entered a holder of the ordinary type and of about 1,000 cubic feet capacity. Plate XI, *A* illustrates the dry scrubber and gas holder.

After a shutdown of several hours, or when a new fire was being started, the first gas from the producer was usually incombustible, or at least of very poor quality and unfit for use in the engine. A second purge pipe was provided near the outlet of the exhauster, through which, by the manipulation of valves, the gas could be discharged into the atmosphere instead of into the holder until it was of the proper quality.

From the holder the gas passed through a meter to the engine. The same meter used during the tests made at St. Louis and Norfolk was installed at Pittsburg. It was calibrated from time to time and gave very satisfactory results.

The three-cylinder vertical Westinghouse gas engine was of the same type as the one used heretofore, but smaller, being rated at 150 brake horsepower. The engine was equipped for taking indicator cards from each cylinder. Outside-spring gas-engine indicators were used and cards were taken at frequent intervals. The engine was also provided with a variable ignition device, which enabled the operator to readily change the time of ignition while the engine was running. The ignition current was supplied principally by a small motor-generator set, but a storage battery was held in reserve for any emergency and for starting. An illustration of the engine and meter is shown in Plate XI, *B*. The engine was belt-connected to a 175-kilowatt Westinghouse direct-current generator, which was the same machine used throughout the St. Louis tests. Before beginning the work at the Pittsburg station, however, the generator was calibrated and its efficiency determined for different loads.

Throughout each test power was supplied to several motors at the plant, but the amount required for this purpose was variable and usually much less than the desired load. Full load was maintained by the use of a water rheostat in the same manner as at St. Louis and Norfolk. The rheostat used at Norfolk is illustrated in Plate VIII, *A* (p. 86). The load was determined by voltmeter and ammeter readings; and the current required for driving the exhauster was measured by means of a wattmeter. These switchboard instruments were of a standard make, and were calibrated by comparisons with standard laboratory instruments.

The calorific value of the gas was determined by a Junker calorimeter. Figure 217 shows the arrangement of apparatus for taking gas samples for analysis, and also for supplying gas to the calorimeter. A half-inch pipe was inserted, as shown, along a diameter of the gas main leading from the gas holder to the engine. In this small pipe were several holes, the total area of which was approximately equal to the cross-sectional area of the half-inch pipe. Connection was made from a gas cock to the calorimeter by means of a rubber tube. During the first tests instantaneous gas samples for analysis were taken at regular intervals, but in all subsequent tests continuous samples were taken. These samples were taken over mercury, and the time over which the sampling extended, usually about two hours, was controlled by an adjustment of the rate at which the mercury ran from the gas-sample holder shown at *a*. A flow of gas was maintained through the gas-sampling pipe by a Bunsen burner, as shown in the illustration. This prevented any accumulation of gas in the pipe, which might vitiate the sample.

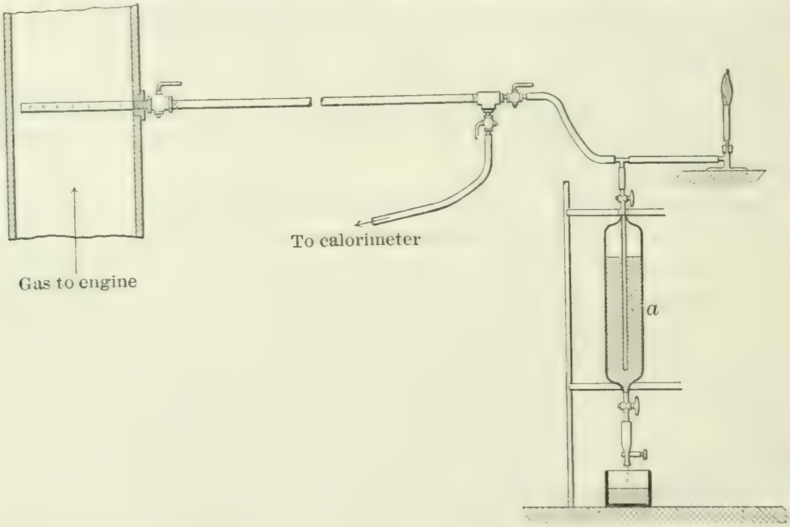


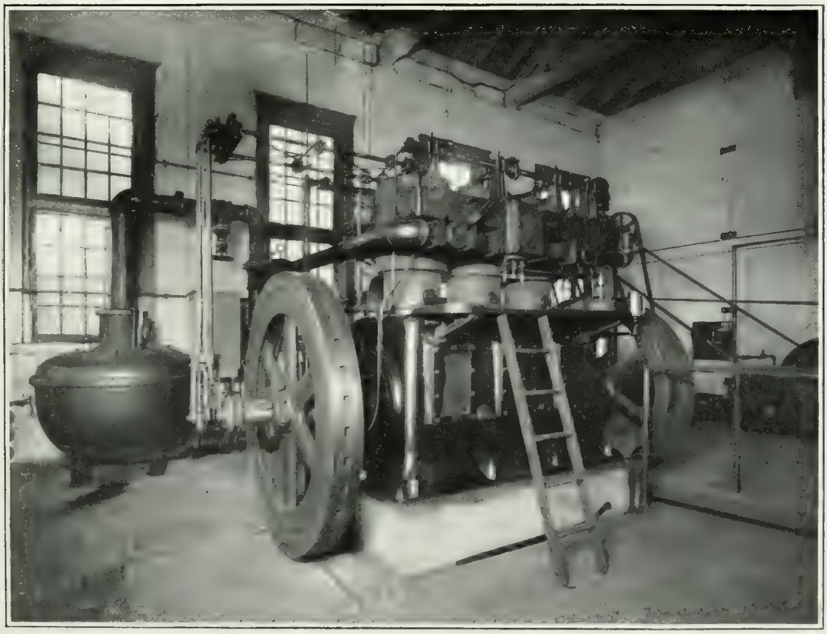
FIGURE 217.—Gas-sampling apparatus.

Hemple's apparatus was used in making the gas analyses, special attention being given to details of manipulation and to the use of solutions. Caustic potash, fuming sulphuric acid, pyrogallic acid, and cuprous chloride were used in the order named. Methane and hydrogen were determined by slow combustion over mercury. Nitrogen was determined by difference.

Experimental work investigating the comparative accuracy of different methods of gas analyses is now being carried on at the testing station. The results of this investigation will be published in a bulletin of the Bureau of Mines.

The factors used in calculating the heat value of the gas from the analysis were taken from Thompson's Thermochemie Unter-

A. GASOMETER AND COOLING TOWER AT PITTSBURG PRODUCER-GAS PLANT.



B. GAS ENGINE AND METER AT PITTSBURG PRODUCER-GAS PLANT.

suchungen. These values, for standard conditions of temperature and pressure (62° F. and 14.7 pounds pressure), are as follows:

Carbon monoxide (CO), 329 B. t. u. per cubic foot; hydrogen (H_2), 328 B. t. u. per cubic foot; methane (CH_4) 1,004 B. t. u. per cubic foot.

A concrete muffler, buried in the ground, muffled the engine exhaust satisfactorily. It was of the same construction as that used at Norfolk, which is described on page 85.

In order to lessen the amount of water consumed, the gas-engine jacket water was discharged to a cooling tower, and from there to a large reservoir or cistern, where it was again available for use. In the illustrations on Plate XI, *A* the cooling apparatus is shown situated between the dry scrubber and the gas holder. Plate XII, *A* gives an illustration of the auxiliary equipment, consisting of a 10-horsepower gas engine *a*, air compressor *b*, gas compressor *c*, compressed-air tanks *d*, and a motor *e*. The compressed-gas tank of about 35 cubic-feet capacity is shown in figure 214. In the operation of the producer compressed gas was required from time to time to loosen up the fuel bed, which had a tendency to pack and thereby increase the resistance to the passage of the gases. For this purpose gas at about 125 pounds pressure per square inch was used.

All water used was measured by meters of the piston type, which were so installed that they could be easily calibrated at any time. The temperature of the gas leaving the producer was measured by a platinum-rhodium thermocouple and a Siemens & Halske galvanometer. All other temperatures were determined by thermometers of a standard make. Calibrations of thermometers were made by comparisons with standard laboratory instruments. Pressures were determined by the use of manometers; these were conveniently situated and were connected by piping to points of the plant at which it was desirable to know the pressures. Plate XII, *B* shows the arrangement of several manometers.

Platform scales were used for weighing all fuel charged into the producer, and from time to time they were checked with standard weights.

OPERATING CONDITIONS.

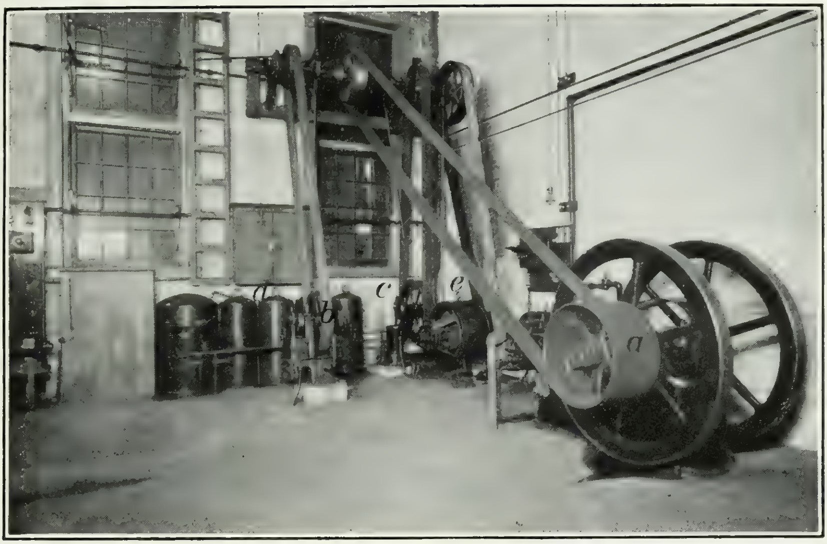
In a producer of the down-draft type accumulation of ash and refuse can not easily be removed when the plant is in operation, or without removing the entire fuel bed. Consequently, it is necessary to shut down from time to time in order to clean out these accumulations and to remove clinkers which frequently adhere to the producer walls. The length of time the producer can be operated continuously depends to a great extent upon the quantity and character of ash in the fuel. Inasmuch as many of the low-grade fuels tested at the Pittsburg station were high in ash, no attempt was made to operate the producer longer than one test period without dumping the fuel bed and thoroughly cleaning out all refuse matter.

The especial feature of a down-draft producer is the generation of tar-free gas. That this function may be properly performed, it is necessary to maintain an incandescent bed of coke, generally called a "fixing bed," through which the tar vapors pass and become fixed or changed into permanent gases by the action of the intense heat.

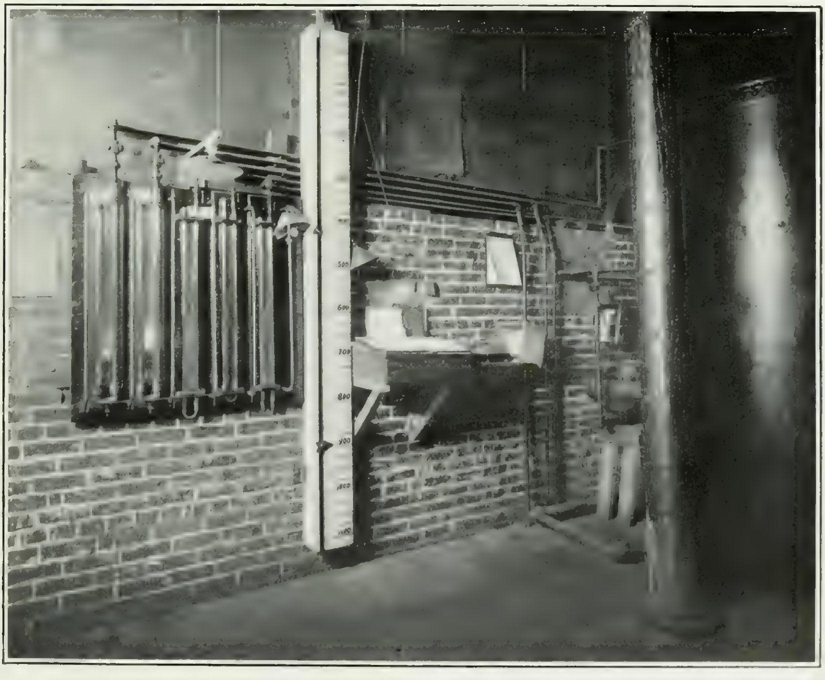
In the producer installed at the Pittsburg station a quantity of coke was used at the beginning of each test to form a fixing bed. The coke was placed upon the fire-brick grate in a layer about 2 feet thick, but this amount varied according to the character of the fuel to be tested, more being used with a lignite than with a coking coal. The fire was usually kindled with wood placed on top of the coke; sometimes, however, a layer of the fuel to be tested was first charged on top of the coke and the fire started on top of this. At the time of lighting the fire the exhauster was started to produce the necessary downward draft, and the valves were set so as to discharge the gases through the purge pipe into the atmosphere. As soon as the fire was burning well, fuel was charged as fast as it would ignite readily and until an effective working fuel bed was built up. The first gases formed were products of complete combustion, but as the fuel bed increased in thickness the quality of the gas gradually improved. It ordinarily required about an hour from the time the fire was started in the producer before the gas would ignite at the test cock, but this time varied with different fuels. As soon as the gas would burn steadily the engine was usually started. The gas at this time, however, even though it burned readily at the test cock, was generally low in heat value, and for some time following only partial load could be carried at the engine. Before the engine was started the valve in the purge pipe was closed and the holder filled with gas.

During the first part of a run, and while the fuel bed was still comparatively thin, the gas consumption was invariably less than the maximum output of the exhauster, and consequently, through the action of the exhauster by-pass, the draft on the producer was materially diminished. Frequently the effect of the decreased draft was to cool the fuel bed to such an extent as to cause a decrease in the heat value of the gas, and thus affect the operation of the engine.

In order to maintain a draft sufficient to prevent undue cooling of the fuel bed at such times, it was necessary to open the purge valve slightly and allow a portion of the gas to escape into the atmosphere. Thus the quantity of gas drawn from the producer was increased and likewise the draft. But as the fuel bed increased in thickness, the



A. AUXILIARY EQUIPMENT AT PITTSBURG PRODUCER-GAS PLANT.



B. PRESSURE GAGES AT PITTSBURG PRODUCER-GAS PLANT.

temperature also increased and the quality of the gas improved, and after 3 or 4 hours' operation it was usually unnecessary to keep the purge pipe open.

After a fuel bed 3 to 4 feet in thickness had been built up coal was charged into the producer less frequently and in smaller quantities than at first, care being taken to keep the fire uniform and to prevent the formation of chimneys or large open passages through the fuel bed.

The charging of fuel from the top of the producer and the downward draft had a tendency to pack the fuel bed, and thus to increase its resistance to the passage of gas. The accumulation of ash, which increased as the run progressed, also tended to retard the velocity of the gas. The resistance of the fuel bed was measured in inches of water by a manometer connected with the base of the producer, and throughout a run this resistance varied from about 2 inches to 20 or 30 inches, according to the condition of the fuel bed and the character of the fuel used. With a high resistance of the fuel bed the quantity of gas that could be drawn from the producer was decreased, and frequently the quality of the gas was impaired. In order to reduce the resistance and to prevent its gradual increase throughout a run, the fuel bed was loosened from time to time by shooting. This was accomplished by admitting compressed gas beneath the fire-brick grate at a pressure of about 125 pounds per square inch. Before this was done, however, the charging door was closed and securely fastened and the purge pipe leading from the top of the producer was opened. A valve in the gas line near the outlet of the producer was closed, and immediately the compressed gas was suddenly admitted to the ash pit. The only exit was up through the fuel bed and purge pipe to the atmosphere, and the effect was to thoroughly loosen the fuel bed. Much fine material which collects during the operation of the producer and fills the interstices of the fuel bed was blown out. The resistance of the fuel bed was thus materially reduced, frequently from 25 inches of water before shooting to only 3 or 4 inches after shooting. Sometimes, however, with a fuel having excessive clinkering tendencies, a shot had little or no effect on the resistance of the fuel bed. The frequency with which it was necessary to shoot the fire depended upon the fuels used, some requiring several shots each day, whereas with others one shot each day was all that was necessary. From 1 to 2 minutes were required to make a shot, and during this time the engine drew on the gas reserve in the holder, which contained a sufficient quantity of gas to run the engine for a period of from 6 to 8 minutes. Generally a shot produced no effect upon the quality of the gas, but sometimes the calorific power was reduced, while at other times it was increased. During the operation of the producer a pilot light or test flame was kept burning, which served to give the operator an indication of the quality of the gas and acted as a guide in handling the producer.

Owing to the poor grade of the fuels tested, it was difficult to generate at all times a gas of uniform quality or of sufficient calorific power to sustain the rated full load at the engine. When the gas was of too low heat value to enable the engine to carry its rated load, the maximum load that could be carried was maintained. Of the tests made, two were partial-load tests, and in these no attempt was made to carry the maximum load.

During each test a record was made of the time and quantity of each fuel charge. The temperature and pressure of the gas at different points in the producer plant were observed and recorded hourly, as were also all water-meter readings. The gas-meter and switchboard readings and the jacket-water temperatures were recorded every 20 minutes.

Tests 170 to 183, inclusive, and test 195 were continuous, but in tests 184 to 194, inclusive, the plant was operated 9 hours a day, with fires banked at night.

The indicated horsepower developed in the tests has been determined from the curve shown in figure 218. Indicator cards, however, were taken frequently, and they were of great value to the engine operator as an aid in determining the proper valve settings and time of ignition; but owing to the conditions of variable load and irregular intervals under which the cards were taken, their use as a measure of the indicated horsepower is rather unsatisfactory. It is probably true that the values obtained from the curve are frequently somewhat in error, but it is believed that they are more reliable than when computed from the cards. The curve is based upon 25 sets of carefully selected indicator cards, taken at various loads but with the engine running steadily. The cards were taken simultaneously with switchboard readings. Each set consists of three cards, one for each cylinder of the engine. These cards were carefully computed, and the indicated horsepower obtained for each set was platted against the electrical horsepower observed. Typical indicator cards, together with the computed data, are given for several of the tests.

RESULTS OF TESTS.

Pittsburg No. 1, test 170.—The fuel used during this test was called nut coal, but it contained a large percentage of slack and little lump or nut. This was the first run made after the installation of the plant, and it was more in the nature of a trial run than a test. Most of the observations were recorded, however, and the results of the run are presented in the table on page 352. Throughout the run of 69 consecutive hours no special attempt was made to secure efficiency or economic results, but rather to familiarize the operators and observers with the working details of the entire equipment.

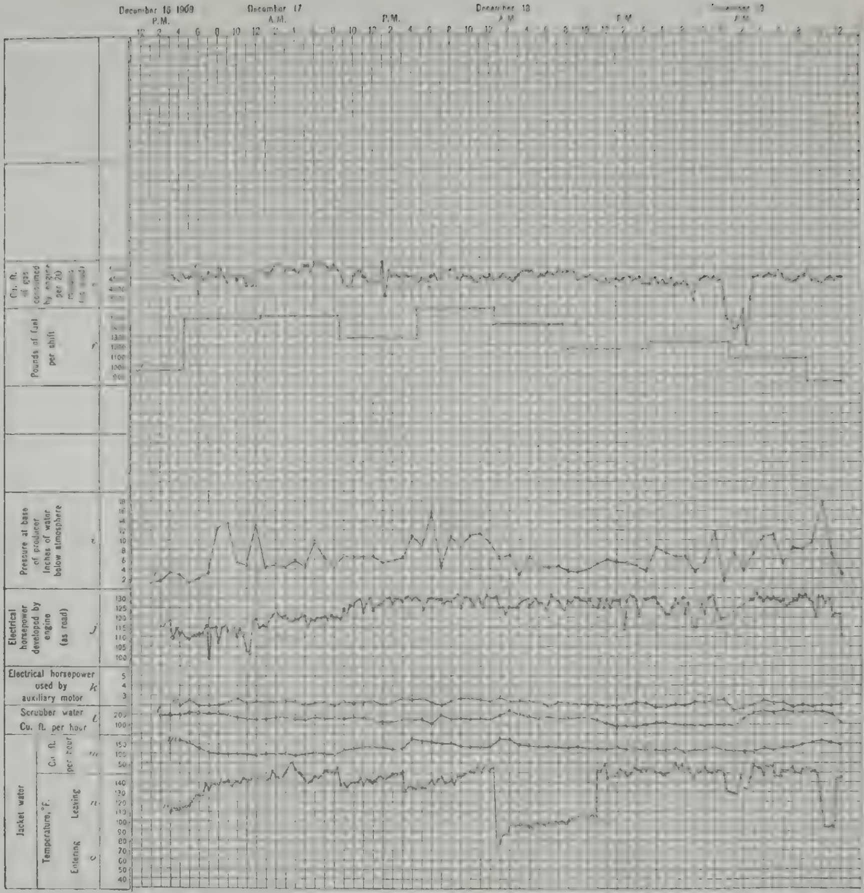


FIGURE 219.—Graphic log sheet, test No. 170, Pittsburg [illegible].

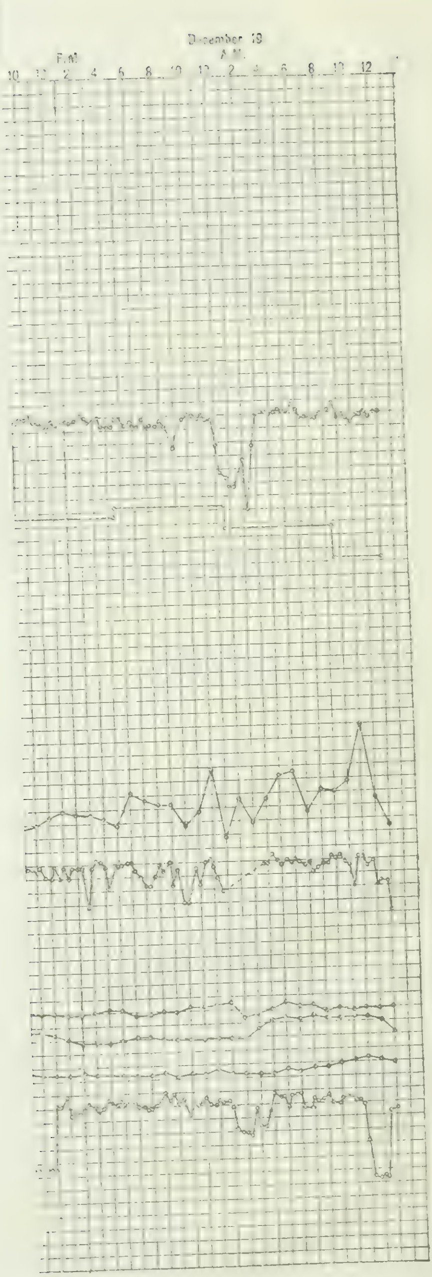


Fig. 1.

During the first part of the run the gas was of poor and rather variable quality, but as the fuel bed was built up the quality of the gas improved and became more uniform. The fuel bed was poked frequently, and during a portion of the run it was shot at intervals of from 1 to 2 hours to prevent an excessive resistance of the fuel bed.

The engine ran steadily throughout the greater part of the test, but at one time a few back fires occurred, and one of the exhaust valves occasioned some difficulty by sticking. These troubles were not serious and were soon remedied. The load varied somewhat, as is shown by the graphic log (fig. 219).

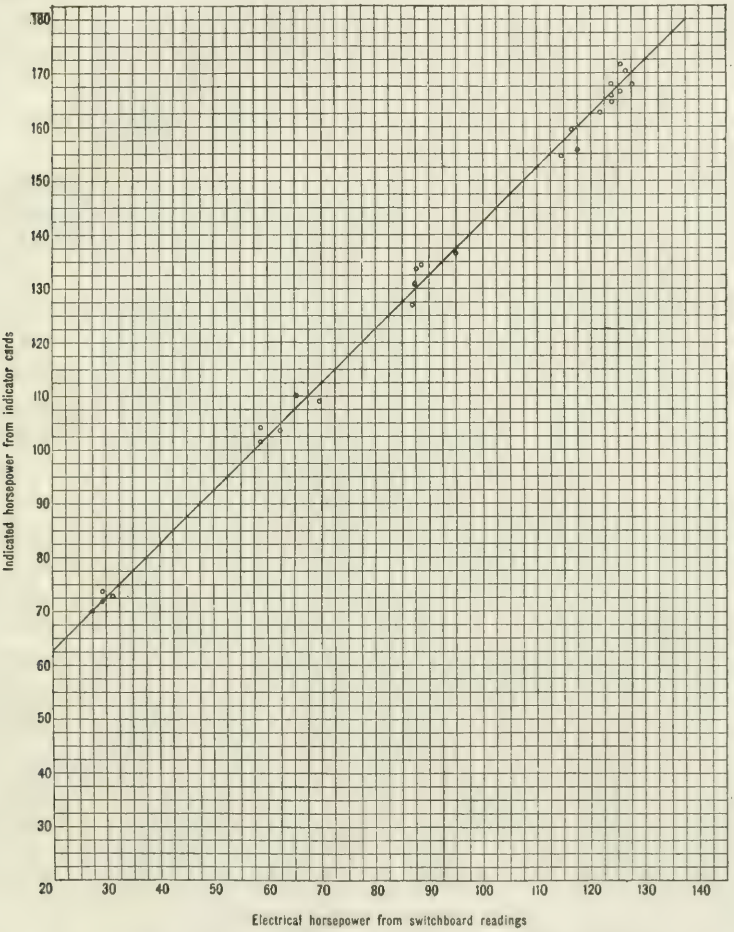


FIGURE 218.—Curve showing relation of indicated and electrical horsepower.

At the close of the run about 350 pounds of clinkers were removed from the producer. Graphic log is given on page 325 (insert).

Pittsburg No. 1A, test 171.—This was a continuous test of 38 hours. The fuel used was a roof coal containing over 15 per cent of ash, and was delivered to the producer platform in lumps up to 8 or 10 inches in diameter. Some lumps contained a large proportion of slate or shale, whereas others appeared to consist entirely of high-grade coal. The lumps were broken up before the coal was fired.

An hour and eighteen minutes after the fire was started combustible gas from the producer was available.

An accumulation of clinker caused the resistance of the fuel bed to increase gradually throughout the test, and necessitated frequent shooting. The resistance of the fuel bed is shown by curve *i* of the graphic log (fig. 226), and is given in terms of the negative pressure or suction at the base of the producer. From this curve the effect of shooting is readily seen by the abrupt decrease in the suction, indicating a decrease in the resistance of the fuel bed.

As the chemical laboratory had not been completed at the time of this test, no heat value determinations or analyses of the gas were made. Several temperature readings were also omitted due to the lack of thermometers.

The quality of the gas, as indicated by the behavior of the engine, varied somewhat during the test, generally falling off in heat value after shooting the fuel bed. The load carried was also variable, and at the beginning of the test only a light load could be maintained. Full load, however, was easily carried during portions of the run but it could not be steadily maintained because of the variable quality of the gas. At the close of the test a large quantity of clinker was found firmly attached to the producer walls and extending across the entire fuel bed. Graphic log is given on page 327.

Pittsburg slack, test 172.—The fuel used during this test consisted almost entirely of fine coal. It caked to a considerable extent in the producer, necessitating frequent poking to keep the fuel bed in good condition. During the first part of the run the exhauster gave some trouble, due to a leaking by-pass valve; this made it difficult to maintain a sufficient draft and also to keep the holder filled with gas. Under these conditions the gas was of poor and variable quality, and, consequently, only a small load could be carried. After a run of about 14 hours the plant was shut down and the by-pass valve was repaired. To insure ample suction, the speed of the exhauster was increased a little by a change of the pulleys from which it was driven.

As soon as the repairs and changes were made, which required about 4 hours, the run was continued. No further trouble was experienced with the exhauster, and the gas improved rapidly in quality. The resistance of the fuel bed, however, began to increase, and it became necessary to shoot the fire frequently.

No heat-value determinations or analyses of the gas were made during the test, but changes in the quality of the gas were readily indicated by the behavior of the engine. During the greater part of the test a fairly uniform though not full load was maintained. After about 50 hours' run the resistance of the fuel bed began to increase rapidly in spite of efforts to keep it low by shooting the fuel bed. The gas also decreased in heat value, making it necessary to reduce

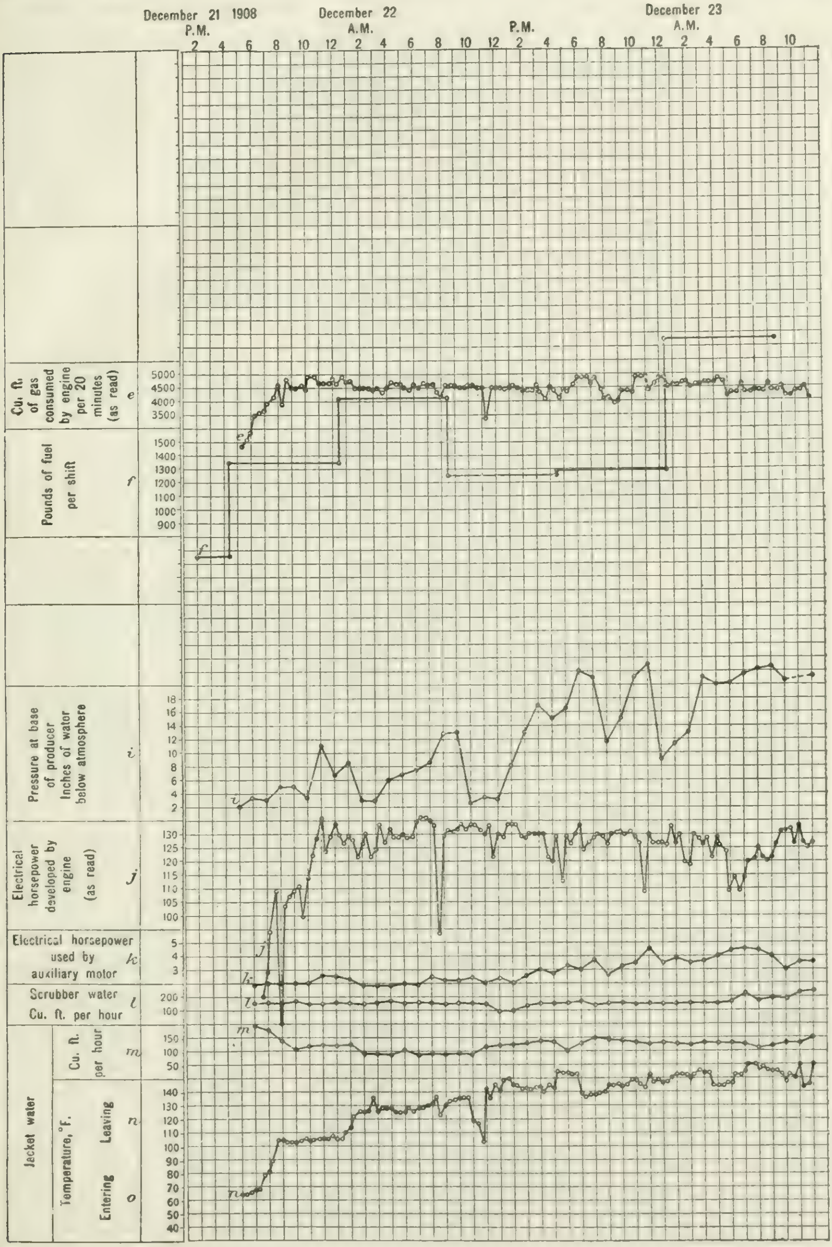


FIGURE 220.—Graphic log sheet, test No. 171, Pittsburg No. 1A coal.

the load. Finally, after a run of 53 hours, the engine stopped on no load, the gas being too poor to operate it. In cleaning out the producer at the close of the run the fuel bed was found to contain a large amount of clinker, which was firmly attached to the producer walls, and which had caused the high resistance of the fuel bed. Graphic log is given on page 328 (insert).

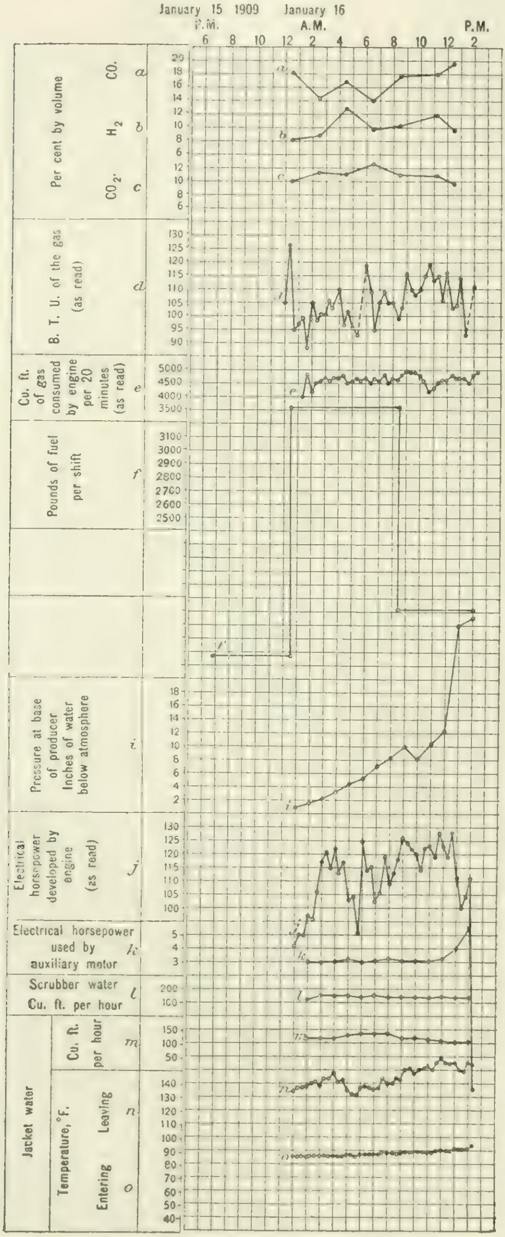


FIGURE 222.—Graphic log sheet, test No. 173, Pittsburg No. 4 coal.

Pittsburg No. 4, test 173.—The fuel used during this test was a briquetted peat from North Carolina. The peat briquets were hard and firm and appeared to be very dry. However, a proximate analysis of the sample taken during the test showed about 14 per cent of moisture. The amount of peat available limited the duration of the test to a little over 14 hours, and, unfortunately, a leak which developed in the gas-outlet pipe of the producer during the test further impaired the value of the results obtained. They are given, however, in the table on page 352.

In the producer the peat worked well, the fuel bed requiring no poking or shooting until toward the end of the run. The resistance of the fuel bed, however, increased gradually throughout the test, and at the close it was exceptionally high. During this test calorimetric determinations and analyses of the gas were made. The heat value of the gas was variable, and was impaired to a consid-

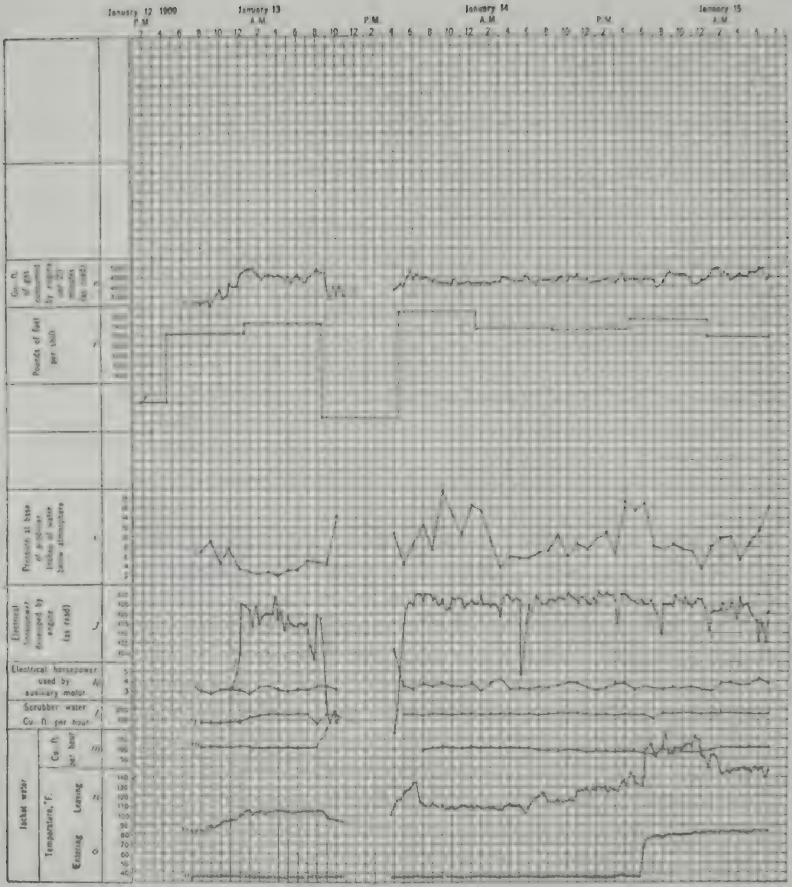


FIGURE 221.—Graphic log sheet, test No. 172, Pittsburg slack.

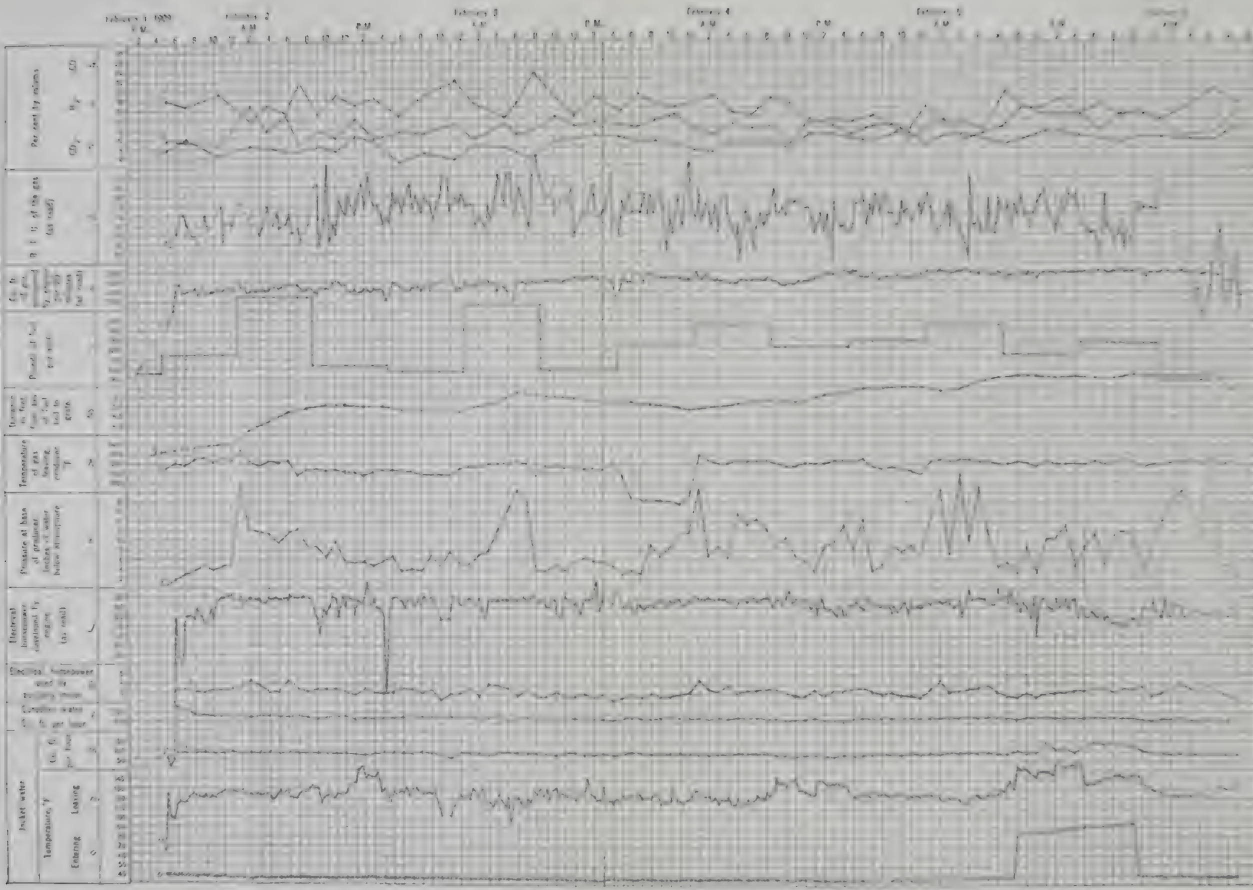


FIGURE 24.—Graphic log sheet, test No. 175. [illegible]

87080°—Bull. 13—11. (To face page 329.) No. 2.

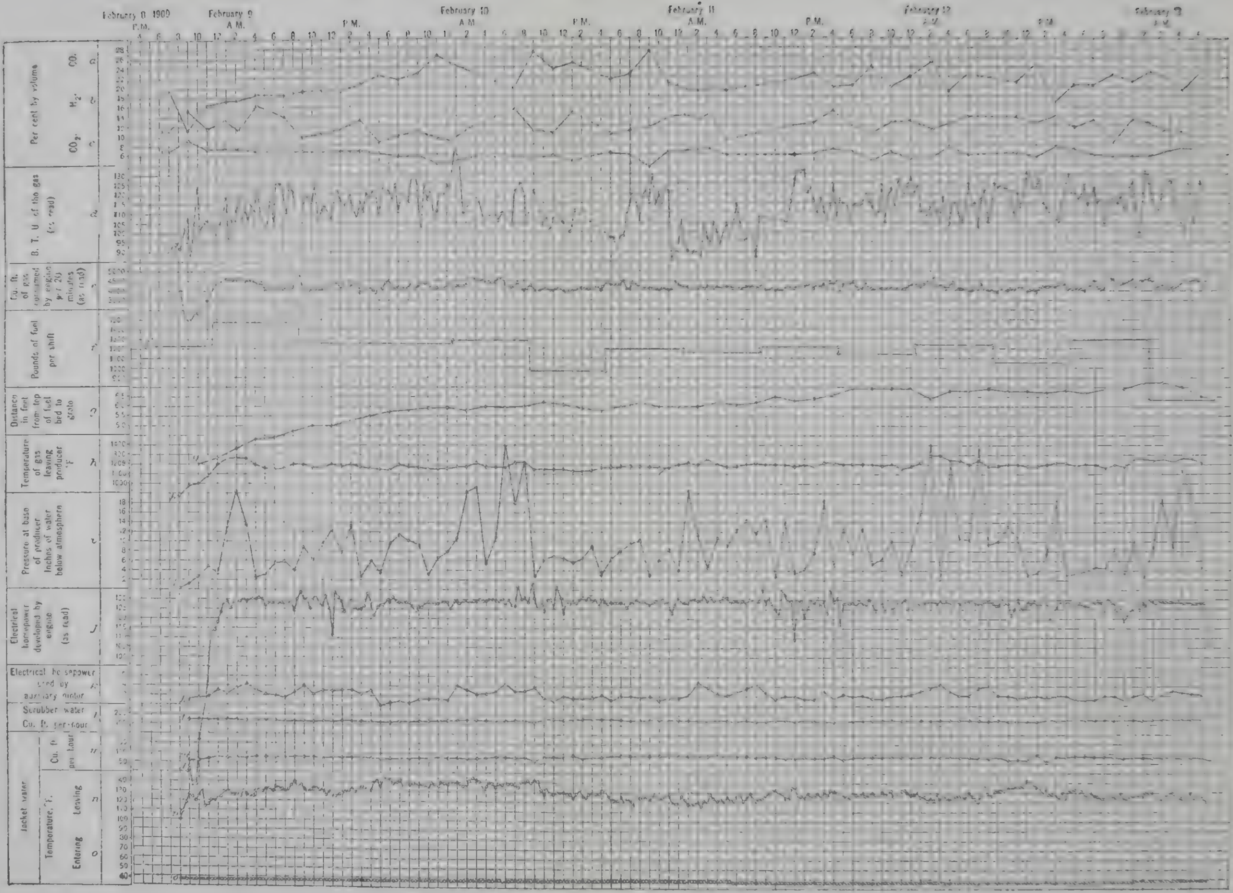


FIGURE 225.—Graphic log sheet, test No. 176, Pittsburg No. 3A coal.

87080°—Bull. 13—11. (To face page 329.) No. 3.

erable extent by the leak in the gas pipe. Its average for the test was 109 B. t. u. per cubic foot. The load carried was rather irregular, as is shown by the graphic log (fig. 223). This peat was unusually high in ash, containing a large amount of silica sand, and as a result there was an excessive amount of clinker formed. Graphic log is given on page 328.

Pittsburg slack, test 174.—Pittsburg slack of the same general character as that fired in test 172 was used throughout this test. It caked considerably in the producer, and the fuel bed had to be poked at frequent intervals. Throughout the test the gas was rather variable in quality, as is shown by the graphic log (fig. 224). Soon after the test started air leaks developed around the clean-out doors of the producer, and it became necessary to shut down in order to stop them. The resistance of the fuel bed was high at times, but usually this was effectively reduced by shooting. During the last 24 hours of the run air leaks gave further trouble, owing to a break in the cast-iron connection between the producer and the economizer. The gas ignited at the break, causing undue heating of the economizer and impoverishing the heat value of the gas to such an extent as to necessitate a reduction in the load. A considerable amount of clinker was formed during the test, but it was removed with little difficulty. Graphic log is given on page 329.

Pittsburg No. 5A, test 175.—The fuel used during this test was a Pocahontas bone coal. It contained about 15 per cent of ash, and as fired had a calorific value of about 12,750 B. t. u. per pound. When delivered to the producer platform the fuel contained about 50 per cent of slack or fine coal, the remainder being lumps, many of which contained slate or shale. Throughout the test of nearly 111 hours the producer was kept in a fairly satisfactory operating condition. The gas, though somewhat variable in quality, gave little trouble at the engine, and practically full load was maintained during the greater part of the test. The resistance of the fuel bed varied throughout the run, but by shooting from time to time it was prevented from becoming excessive. Lampblack was washed from the scrubber continually. A considerable quantity of clinker formed, which adhered to the producer walls in a ring 12 to 18 inches in thickness. In cleaning out the producer this clinker was broken loose easily. Graphic log is given on page 329.

Pittsburg No. 5A, test 176.—This test was made on the same kind of fuel as that used during test 175 but from a different car and apparently of a little better grade, containing about 12 per cent of ash and having a calorific value of approximately 13,725 B. t. u. per pound. The action of the fuel in the producer and its appearance were the same, however, as that of the coal used for the preceding test. The quality of the gas was somewhat variable, but the engine carried a fairly steady load during the greater part of the test. The calorimeter did not work satisfactorily all of the time, and it is probable that many of the fluctuations in the heat value of the gas shown on the graphic log for this test (fig. 225) are excessive. A considerable quantity of lampblack was produced during the run. The resistance of the fuel bed varied widely, but whenever it became unduly high, shooting the bed invariably reduced it to normal conditions, and without apparently affecting the quality of the gas. More clinker formed during this test than in the preceding one, and it was much harder and adhered firmly to the producer walls. Graphic log is given on page 329.

Pittsburg No. 5A, test 177.—Although the fuel used during this test was from the same lot as that used during test 176, it differed somewhat in analysis, being higher in ash and lower in heat value. The test was made as nearly as possible under the same conditions as test 176, except that only about one-half load was carried. Under this condition the producer worked quite satisfactorily; the temperature within the producer, however, appeared to be considerably less than when the producer was operating under full load. The average temperature of the gas leaving the producer during test 177 was 1,013° F., which is 230° F. less than its average temperature during test 176. The quality of the gas throughout the test was variable, as is shown by the graphic log (fig. 226), but at all times its heat value was sufficient to enable the engine to carry half load with ease. The resistance of the fuel bed, although somewhat variable, was much more uniform than on full-load tests, and much less shooting was required to keep the resistance from becoming excessively high. The test was interrupted for a short time after a run of about 50 hours by the breaking of a valve spring on the engine. This necessitated a shutdown, but repairs were soon made and the test continued. Much less clinker formed during this test than during test 176; nevertheless, a considerable quantity adhered firmly to the producer walls. The effect on fuel economy of running at half load is readily seen by comparing the results of tests 176 and 177, as given in the table on page 357. The producer efficiency dropped from 68 per cent at approximately full load, to about 61 per cent for half load, and the fuel consumption per brake-horsepower hour increased 32 per cent. Graphic log is given on page 330.

Pittsburg No. 5A, test 178.—Pittsburg No. 5A coal, taken from the same carload lot as the fuel for test 177, was used for this run. In analysis and heat value the two lots corresponded closely. Throughout this test different loads were maintained during different portions of the run, as is indicated by the graphic log (fig. 227), quarter load, half load, three-quarter load, and practically full load, respectively, being maintained for periods of about 24 hours each. At the

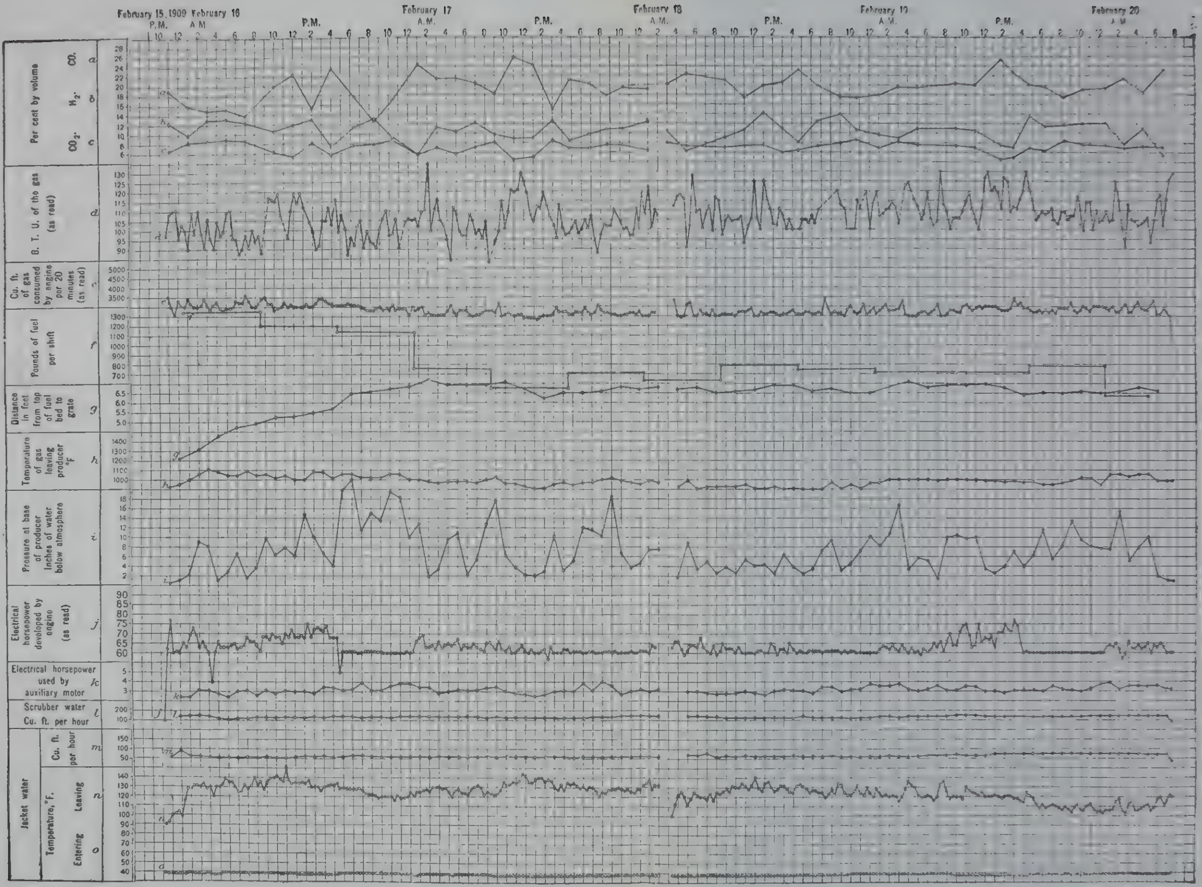


FIGURE 226.—Graphic log sheet test, No. 177, Pittsburg No. 5A coal.

87080°—Bull. 13—11. (To face page 330.) No. 1.

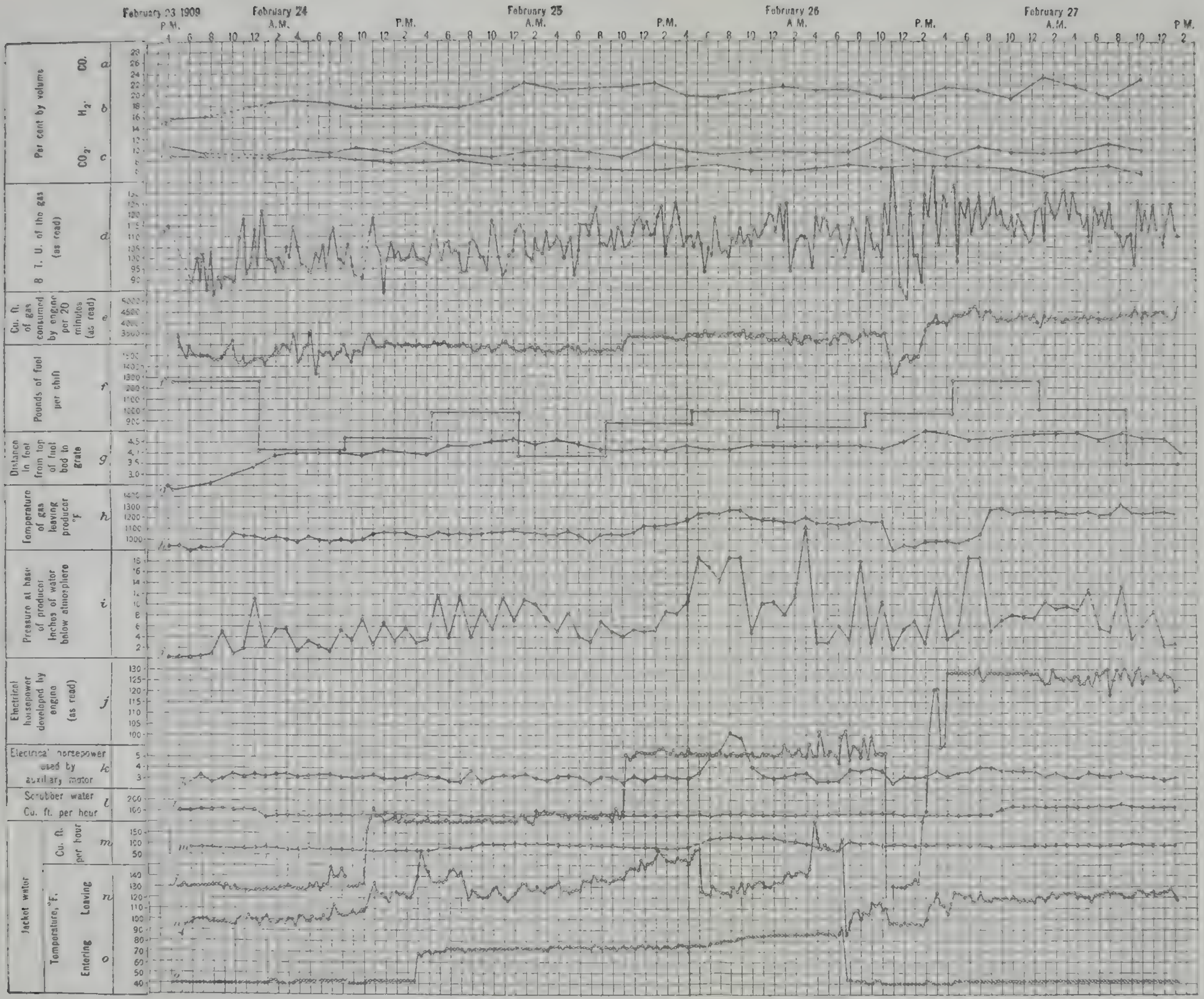


FIGURE 227.—Graphic log sheet, test No. 178, Pittsburg No. 5A coal.

87080°—Bull. 13—11. (To face page 330.) No. 2.

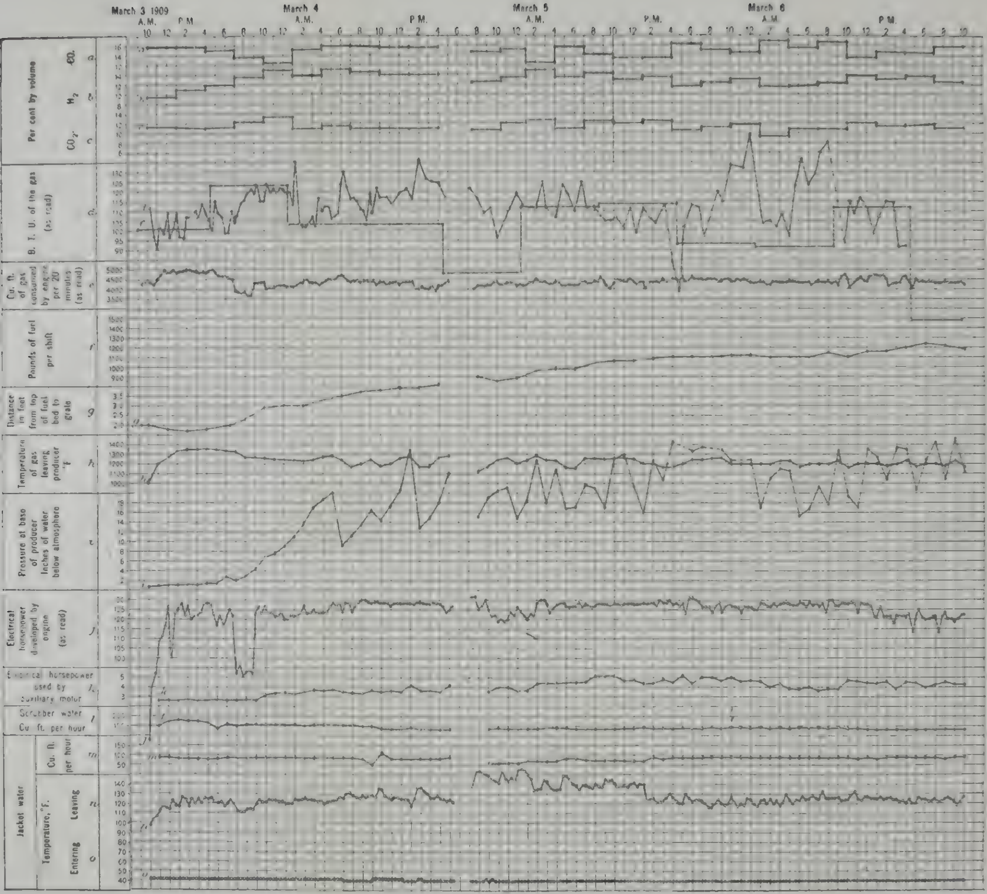
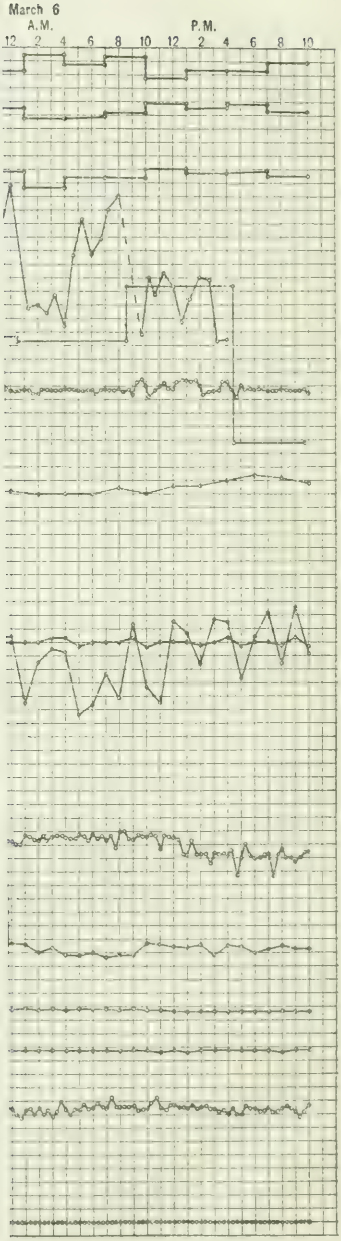


FIGURE 228.—Graphic log sheet, test No. 179, Pittsburg No. 7 coal.


March 6
A.M.
P.M.
12
2
4
6
8
10
12
2
4
6
8
10

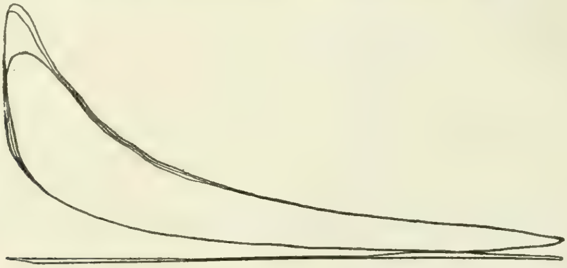
close of the period during which three-quarters load was carried, the switchboard instruments were calibrated in position, and in order to cover the full range of the instruments it was necessary to reduce the load, as is shown by the graphic log. The calorimeter meter gave some trouble from time to time during the test, and although the determined heat values are platted, they can not be regarded as absolutely reliable. The gas gradually increased in heat value, however, as the load was increased, as is shown by the curves giving the analyses. The producer was handled with little difficulty, and comparatively few shots were required to keep the resistance of the fuel bed within normal limits. The fire, however, was poked frequently to prevent the formation of chimneys in the fuel bed. During the run a ring of clinker about 1 foot thick collected on the producer walls. The economic results, as given in the table on page 357, are based upon the average horsepower developed for the entire test. Graphic log is given on page 330.

Pittsburg No. 7, test 179.—The fuel used during this test was a Texas lignite. It was hard and brittle, and in outward appearance was of a dark brown color, but freshly broken surfaces were nearly black. It consisted mostly of small lumps 1 to 2 inches in diameter. There was some slatey looking material in it, but nothing resembling wood as in some lignites. This fuel appeared to be very dry, and when handled it was decidedly dusty. An analysis, however, of the sample taken during the test showed that it contained over 30 per cent of moisture. During the first few hours of the test considerable difficulty was experienced in obtaining a good fuel bed. The lignite did not ignite readily, and the tendency of the fire was to work down into the coke bed. With the combustion zone in the coke bed, an unusually high temperature was produced, which apparently aided in thoroughly igniting the lignite, after which no difficulty was encountered in keeping the fire at the top of the fuel bed. After the first 8 or 10 hours the resistance of the fuel bed increased rapidly, and although numerous shots were made it continued high throughout the remainder of the test. The test was interrupted for about two hours during the second day's run, owing to the sticking of the exhauster by accumulated tar. The tar was probably formed because the greater part of the coke was consumed at the beginning of the test, thus seriously reducing the depth of the fixing bed.

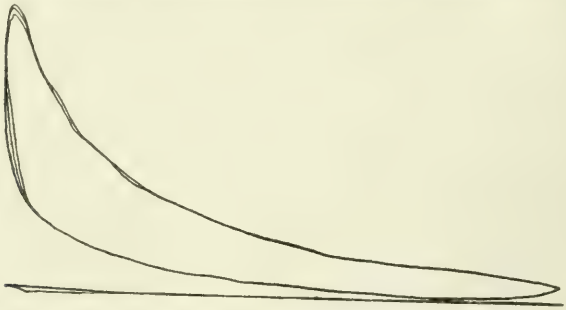
The calorimeter meter gave considerable trouble during the run, owing to traces of tar in the gas. Consequently the results of the heat-value determinations were rather variable and unsatisfactory.

Beginning with this test, the method of taking gas samples for analysis as described on page 319 was first used. All previous analyses were made from instantaneous samples, and the results were platted on the graphic log as points. With continuous samples, however, short horizontal lines have been used instead of points, thus indicating the length of time during which a sample was taken as well as the resulting analysis.

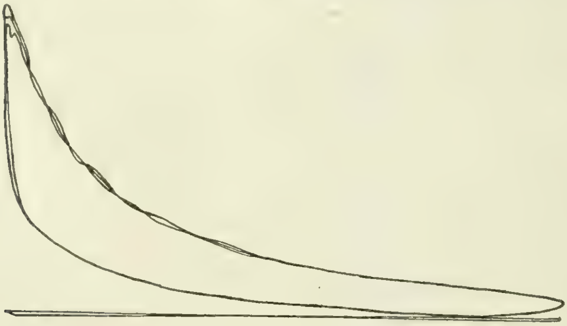
A fairly uniform though not quite full load was maintained throughout the greater part of the test. Toward the last of the run the resistance of the fuel bed was unusually high, the gas fell in heat value, and after a run of 84 hours the test was brought to a close.



Right cylinder: Max. pres., 310 lbs.; release, 22 lbs.; M. E. P., 66.0 lbs.; I. H. P., 54.8.



Center cylinder: Max. pres., 340 lbs.; release, 22 lbs.; M. E. P., 66.0 lbs.; I. H. P., 54.8.



Left cylinder: Max. pres., 373 lbs.; release, 19 lbs.; M. E. P., 63.4 lbs.; I. H. P., 52.6.

FIGURE 229.—Indicator cards taken March 5, 1909, 6.05 a. m., during gas-engine test No. 179 on Pittsburg No. 7 coal. Scale of spring, 200; revolutions per minute, 261.2.

During the test a large amount of clinker formed, which was removed with difficulty. Graphic log is given on page 331.

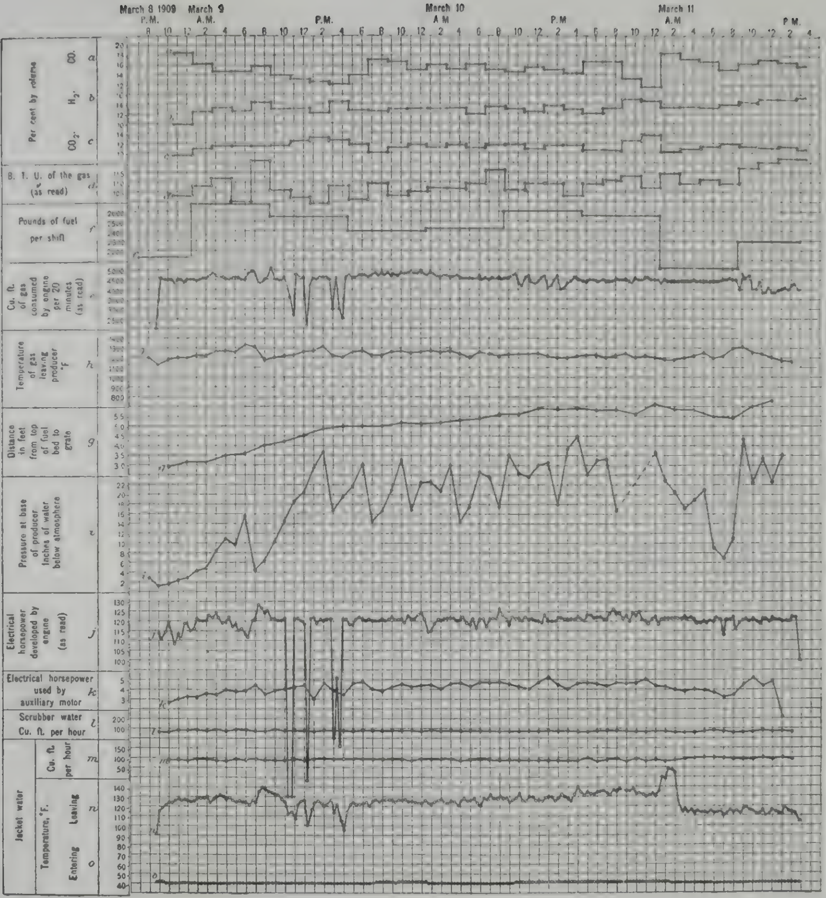


FIGURE 230.—Graphic log sheet, test No. 180, Pittsburg No. 8 coal.

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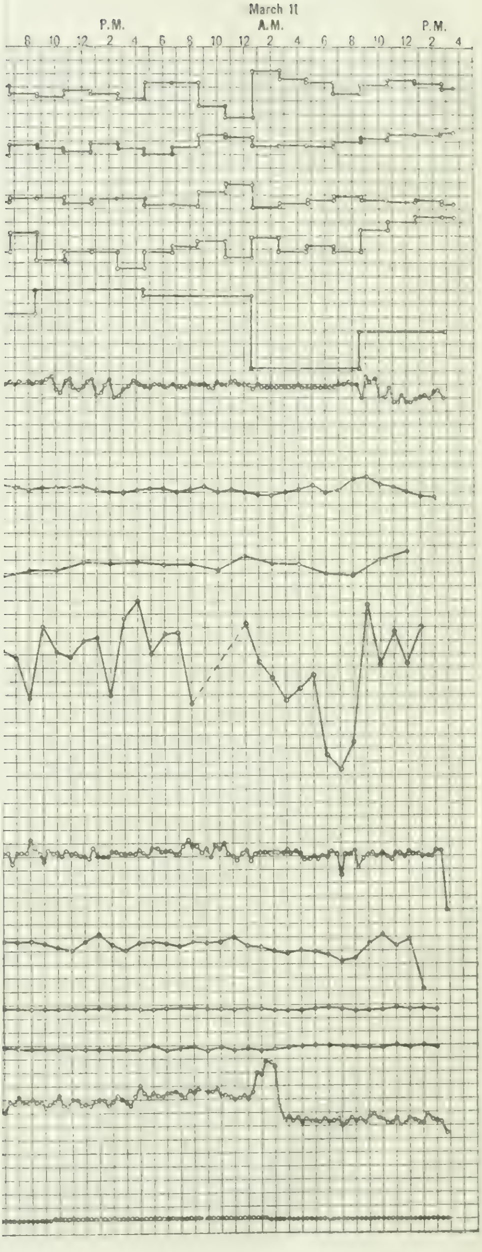
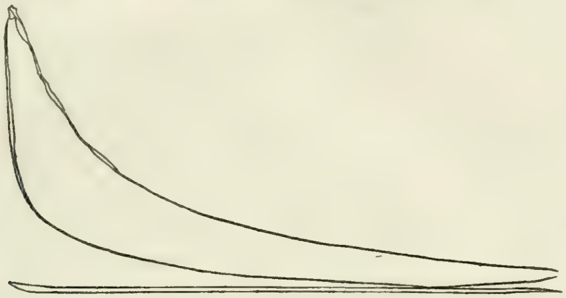
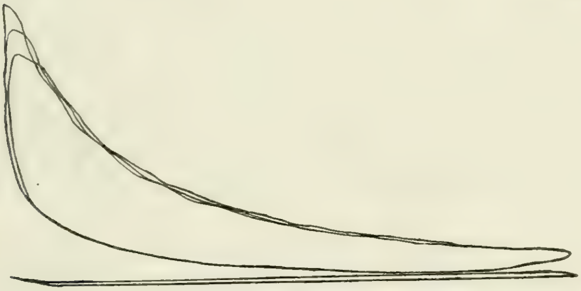


, Pittsburg No. 8 coal.

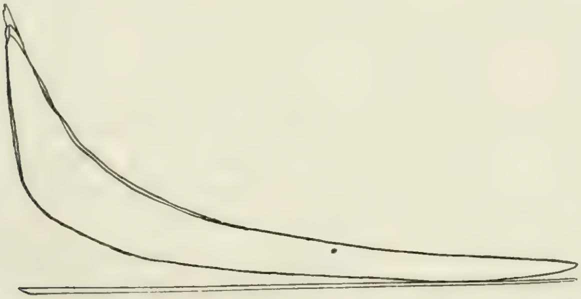
Pittsburg No. 8, test 180.—This test was made on a Texas lignite which in many respects was similar to that used in test 179, being brown in color and of the same general appearance, although somewhat finer. Its action in the producer, also, was very much the same; it ignited slowly at the beginning of the test, and as the fuel bed increased in thickness the resistance increased rapidly, necessitating frequent shots. After each shot a considerable amount of fine material resembling sand was found on top of the fuel bed.



Right cylinder: Max. pres., 342 lbs.; release, 20 lbs.; M. E. P., 60.0 lbs.; I. H. P., 50.0



Center cylinder: Max. pres., 335 lbs.; release, 22 lbs.; M. E. P., 68.7 lbs.; I. H. P., 57.2.



Left cylinder: Max. pres., 350 lbs.; release, 17 lbs.; M. E. P., 56.7 lbs.; I. H.P., 47.3.

FIGURE 231.—Indicator cards taken March 11, 1909, 2.05 a. m., during gas-engine test No. 180, on Pittsburg No. 8 coal. Scale of spring, 200; revolutions per minute, 261.2.

As the calorimeter determinations were rather unsatisfactory, the heat value of the gas was calculated from the analysis and platted, as is shown by the graphic log (fig. 230). During the greater part of the run a fairly uniform though not full load was maintained. After about 12 hours the calibration of the switchboard instruments necessitated a reduction in load for a short period. A large quantity of clinker, which was removed with difficulty, formed during the test. Graphic log is given on page 333.

Pittsburg No. 9, test 181.—The fuel used in this test was a Texas lignite. It was brown in color and rather fine, containing but few lumps, which fell apart in the producer soon after charging, thus making the fuel bed a mass of finely divided lignite.

After running about 10 hours the cracking of a cylinder disabled the engine; the test, however, was continued without the engine after a few hours' shutdown, during which time piping was installed from the meter to the outside of the building. The gas passed through the meter as usual and then through the pipe to its outlet, where it was burned. Gas samples were taken and analyses were made as before. The resistance of the fuel bed was unusually high during the greater part of the run and frequent shots had little effect. Clinker gave considerable trouble during the latter part of the run and at the close of the test the fuel-bed was found to consist almost entirely of clinker. The results of the test as given in the table (p. 352) are based upon the last part of the run, and do not include the time during which the engine was in operation. Graphic log is given on page 334.

Pittsburg No. 9, test 182.—The fuel used during this test was of the same kind and character as that used in the preceding run, namely, Texas lignite. As the engine had not been repaired the test was made in the same manner as in test 181, the gas passing through the meter and then through a pipe to the outside of the building, where it was burned. In this way the gas was produced at a very uniform rate, as there were no fluctuations in the quantity consumed. At the beginning of the test a much thicker coke bed than usual was made in an effort to reduce clinker troubles. The quantity of clinker formed, however, was apparently as great as in the preceding run, but it was removed more readily from the producer. The gas was of fairly uniform quality throughout the test, and the resistance of the fuel bed averaged considerably less than in test 181. Graphic log is given on page 334.

Pittsburg No. 12, test 183.—The fuel used during this test was washery refuse taken from the dump pile of a large coal-washing plant. About half of it appeared to be small lumps of slate and coal, while the remainder consisted of very fine coal and probably some dirt. It contained over 30 per cent of ash, and as fired had a heat value of about 9,900 B. t. u. per pound. This refuse burned readily in the producer, but with a tendency to cake, necessitating poking of the

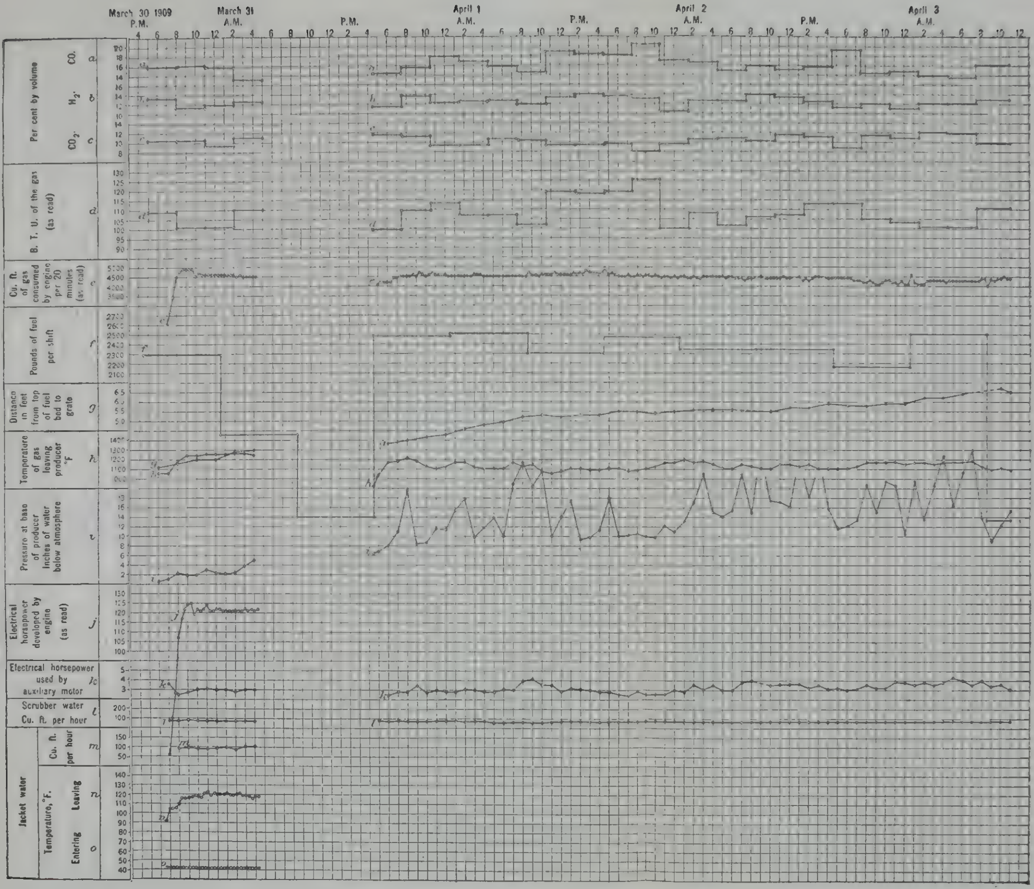


FIGURE 232.—Graphic log sheet, test No. 181, Pittsburg No. 9 coal.

87080°—Bull. 13—11. (To face page 334.) No. 1.

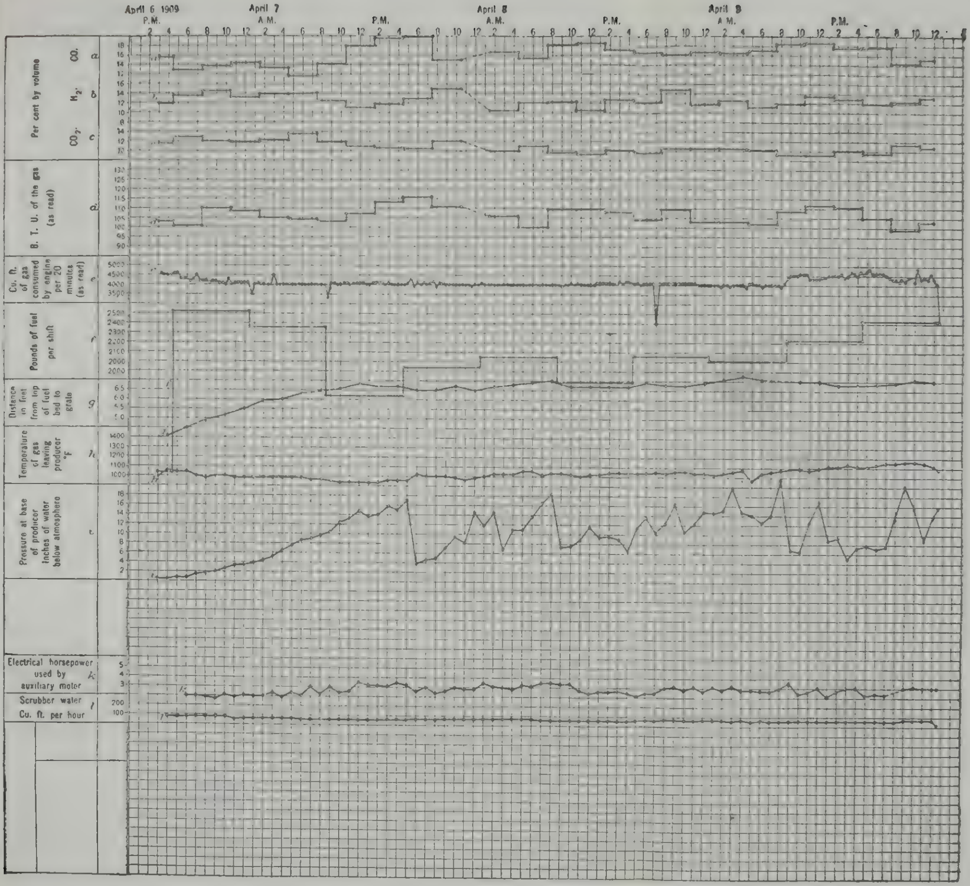


FIGURE 233.—Graphic log sheet, test No. 182, Pittsburg No. 9 coal.

87080°—Bull. 13—11. (To face page 334.) No. 2.

fuel bed at frequent intervals. During the first 10 or 12 hours of the run only partial load was carried by the engine, and consequently

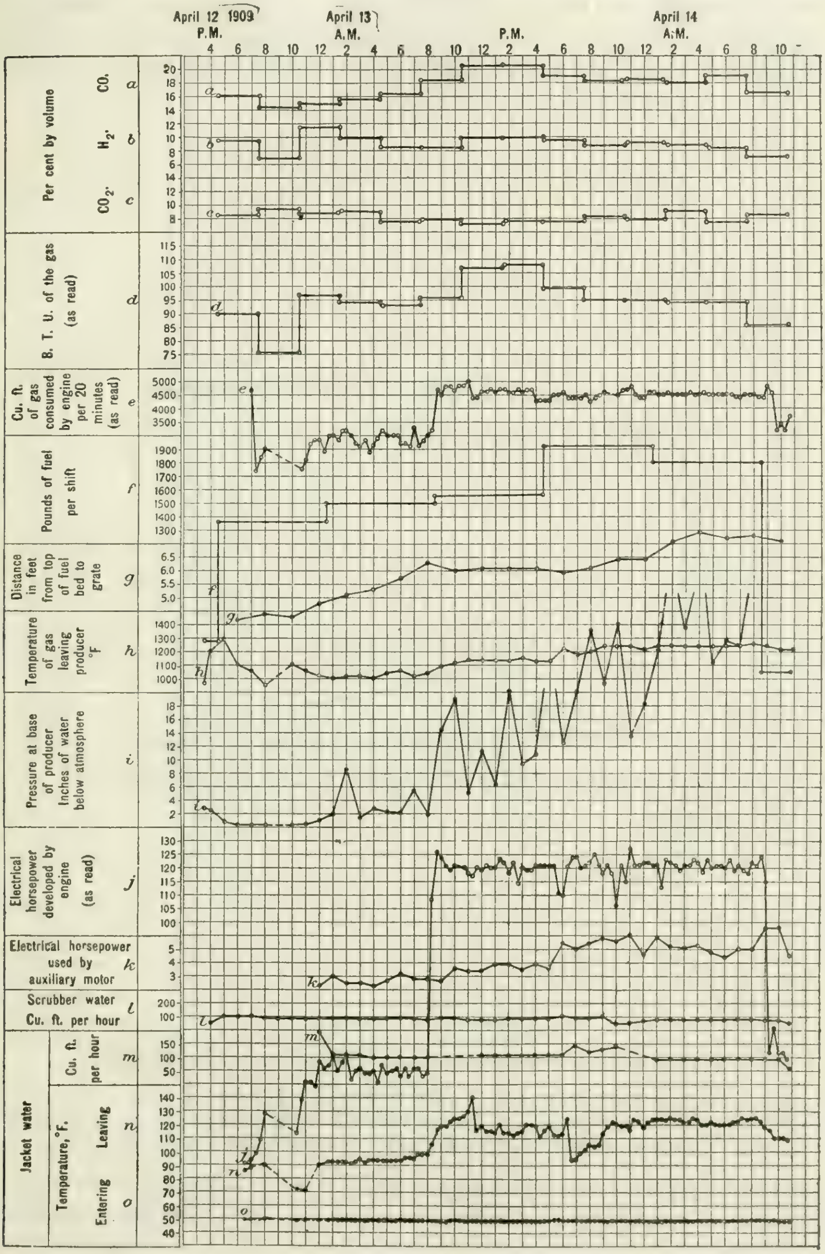
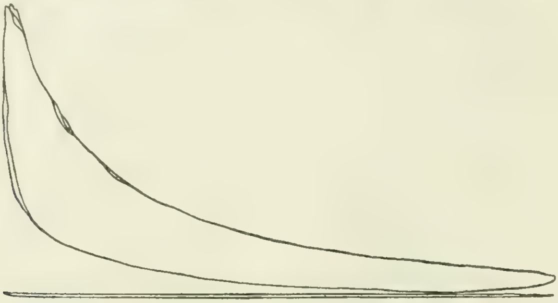
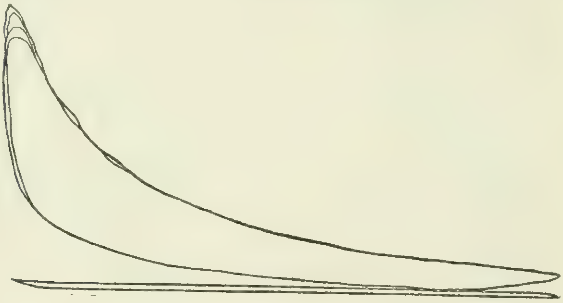


FIGURE 234.—Graphic log sheet, test No. 183, Pittsburg No. 12 coal.

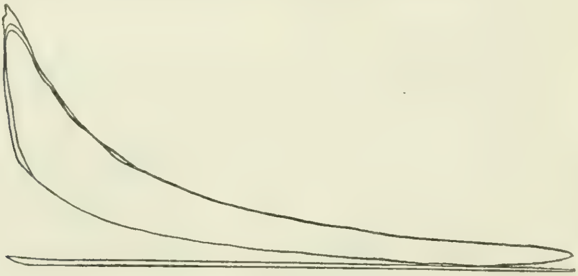
the gas consumption was low. Under these conditions a sufficient quantity of gas was produced with a comparatively small suction on the producer, as is shown by curve *i* of the graphic log (fig. 240). The load was increased, however, to practically full load, and immediately the resistance of the fuel bed began to increase, and during the remainder of the run it was exceptionally high. Toward the last of the test, shooting had little effect on the fuel bed, and the quantity of gas produced decreased to such an extent that it became necessary to reduce the load, and in a short time the run was brought to a close. This fuel produced an excessive quantity of clinker, which adhered firmly to the producer walls. Graphic log is given on page 335.



Right cylinder: Max. pres., 353 lbs.; release, 25 lbs.; M. E. P., 71.3 lbs.; I. H. P., 59.2.



Center cylinder: Max. pres., 340 lbs.; release, 24 lbs.; M. E. P. 69.4 lbs.; I. H. P., 57.6.



Left cylinder: Max. pres., 311 lbs.; release, 22 lbs.; M. E. P., 53.2 lbs.; I. H. P. 44.2.

FIGURE 235.—Indicator cards taken April 13, 1909, 12.05 p. m., during gas-engine test No. 183 on Pittsburg No. 12 coal. Scale of spring, 200; revolutions per minute, 261.2.

Pittsburg No. 13, test 184.—This test was made on a North Dakota lignite. The fuel was dark brown in color, and many of the lumps distinctly showed the grain and texture of wood. The moisture

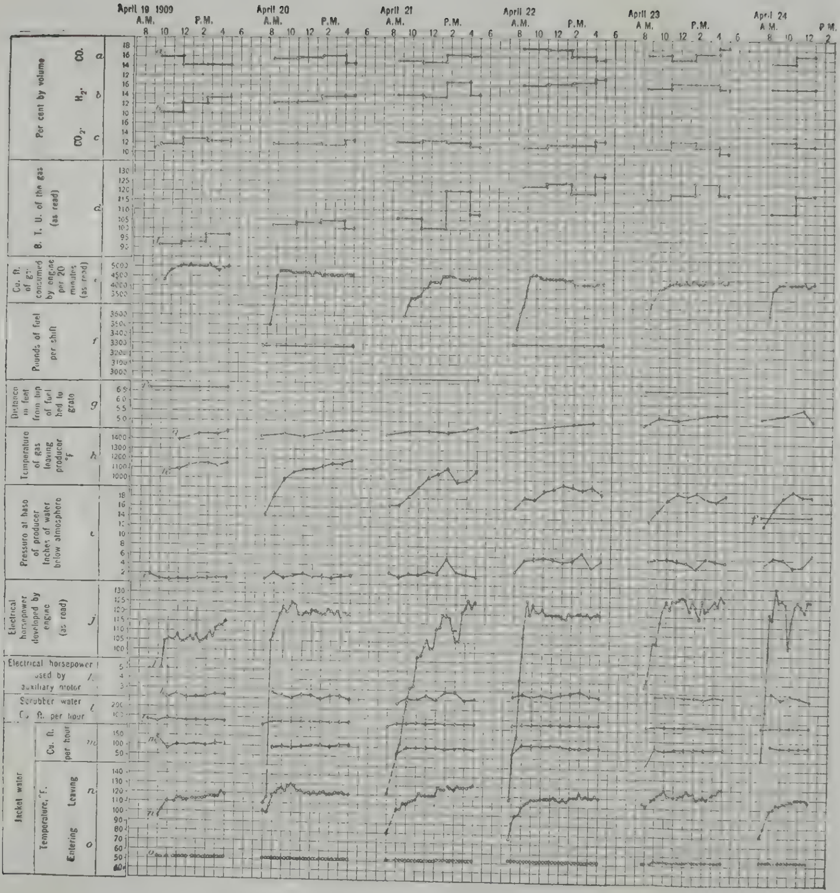
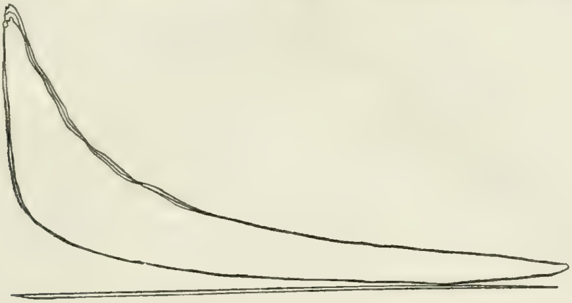


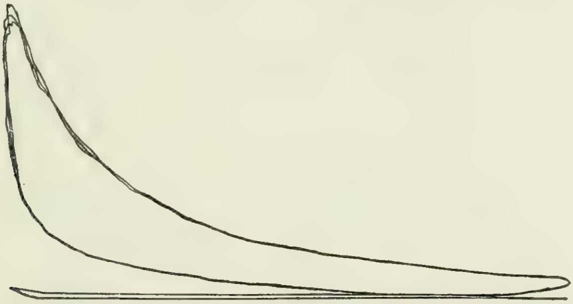
FIGURE 236.—Graphic log sheet, test No. 184, Pittsburg No. 13 coal.

87080°—Bull. 13—11. (To face page 336.)

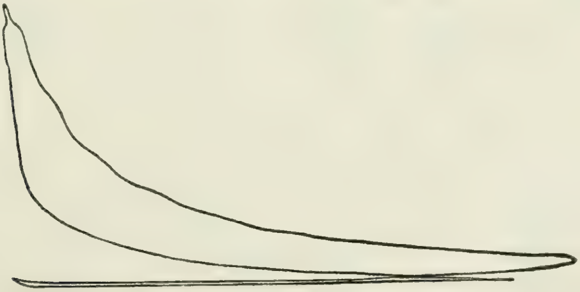
content of the lignite as fired was high, being nearly 35 per cent, and for this reason it ignited slowly when the fire was first kindled. After the fuel bed was burning well, however, the lignite ignited readily and produced a very satisfactory gas. Throughout the test the plant was shut down each night, and during the day it was operated for a period of about 9 hours. The results of the test as given in the table on page 352 are based upon the total quantity of fuel used, no allowance being made for stand-by losses.



Right cylinder: Max. pres., 354 lbs.; release, 24 lbs.; M. E. P., 72.2 lbs.; I. H. P., 60.4.



Center cylinder: Max. pres., 353 lbs.; release, 24 lbs.; M. E. P., 65.6 lbs.; I. H. P., 54.8.



Left cylinder: Max. pres., 377 lbs.; release, 25 lbs.; M. E. P., 57.5 lbs.; I. H. P., 48.1.

FIGURE 237.—Indicator cards taken April 23, 1909, 3.53 p. m., during gas-engine test No. 184, on Pittsburg No. 13 coal. Scale of spring, 200; revolutions per minute, 263.0.

The fire held in the producer over night remarkably well, and usually not over 10 to 15 minutes each morning were required to get the plant in operation. The graphic logs (fig. 236) show each day's performance. The load during the first hour or two of each day's run was light, not because of lean gas, but because the water rheostat was cold and would not take the load. Throughout the entire test the resistance of the fuel bed was exceptionally low, and but few shots were made.

The amount of clinker which formed during this test was small, and in no way interfered with the operation of the producer. Graphic log is given on page 336.

Pittsburg No. 14, test 185.—California lignite was used for this test. It was light brown in color, and consisted principally of lumps, 6 to 10 inches in diameter, which were easily broken. As fired the lignite contained about 38 per cent of moisture and had a heat value of 6,330 B. t. u. per pound. In the producer it burned readily after the fuel bed was well ignited, and it held fire satisfactorily over night, but each morning the producer had to be operated from several minutes to three-quarters of an hour before the gas was of suitable quality to run the engine. The heat value of the gas was variable throughout the test, and it was difficult to maintain a uniform load on the engine. The first day's run was exceedingly short, as is shown by the graphic log (fig. 238). The third day's run was interrupted by a shutdown of about 2 hours, during which time an exhaust valve on the engine was repaired. On the sixth and last day of the test the fuel bed was in poor condition because of clinker; the gas produced was of very poor quality, and the run lasted only about an hour and a half with a light load on the engine. At the close of the test a large quantity of very hard clinker was removed from the producer. The results as given in the table (p. 352) are based on the total coal charged, no allowance being made for stand-by losses. Graphic log is given on page 339.

Pittsburg No. 12, test 186.—During this test washery refuse was again used in the producer, with the hope that more satisfactory conditions could be maintained when operating intermittently than when running continuously. The producer was fired in the usual manner, and as soon as gas was available the engine was started. During the first 2 hours, before the fuel bed was in good working order, the gas was low in heat value and only partial load could be carried; throughout the remainder of the day's run, however, very nearly full load was maintained. The resistance of the fuel bed increased rapidly, but it did not become excessively high during the first day's run. At the beginning of the second day's run the top of the fuel bed was found to be caked into a hard mass, which required much poking to break up. The resistance of the bed was high throughout the entire day, in spite of numerous shots. The gas was low in heat value and only partial load could be carried. Clinker accumulated to a considerable extent, and at the close of the second day's run it so completely filled the fuel bed that no attempt was made to start the next morning. Graphic log is given on page 340.

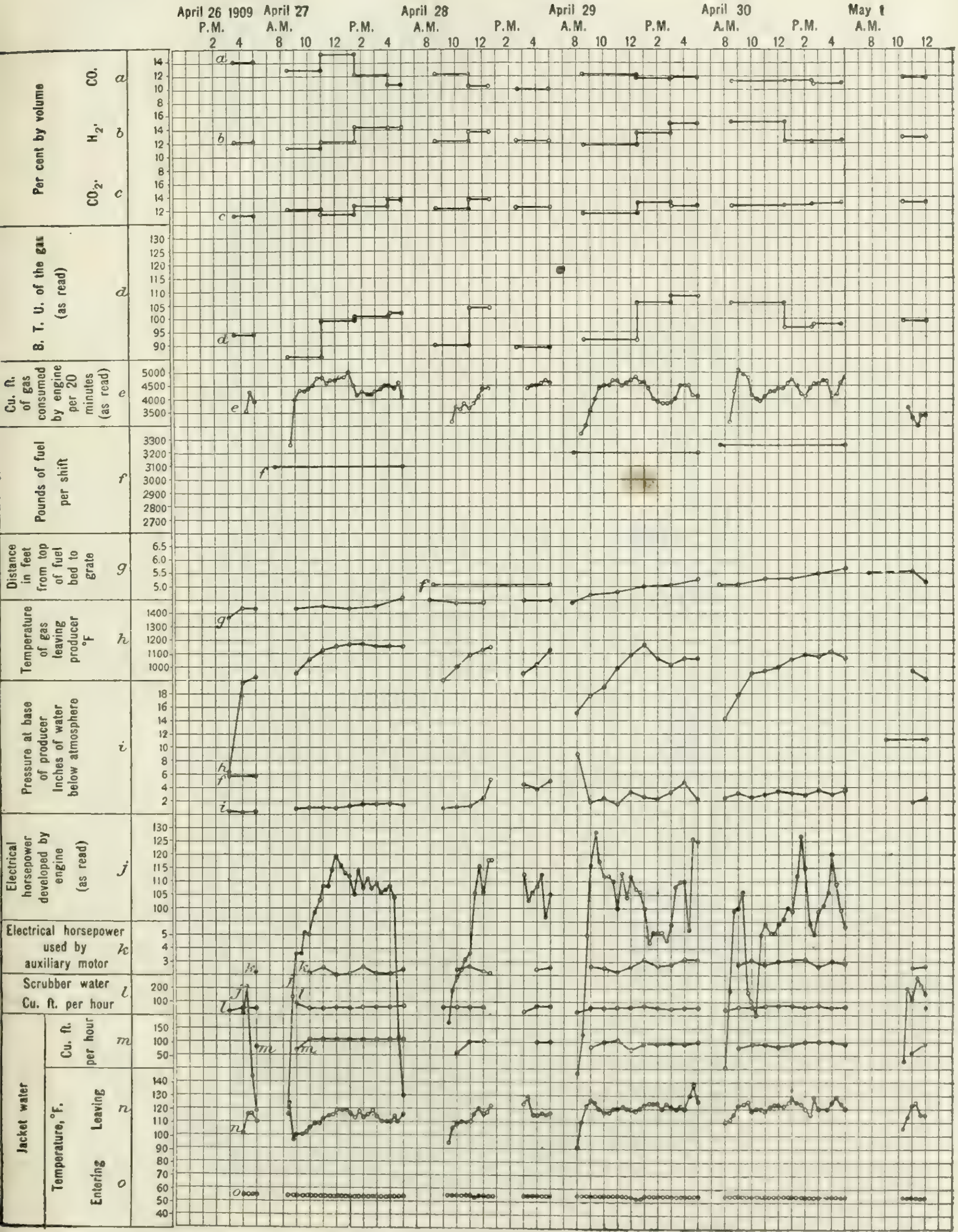


FIGURE 238.—Graphic log sheet, test No. 185, Pittsburg No. 14 coal.

Pittsburg No. 11, test 187.—The fuel used during this test was a lignite from North Dakota. It was of a dark brown color and consisted largely of lumps, which were easily broken. It contained over 30 per cent of moisture, and as fired had a heat value of less than 7,000 B. t. u. per pound. The fuel worked exceptionally well in the producer during the entire test, giving a satisfactory gas and pro-

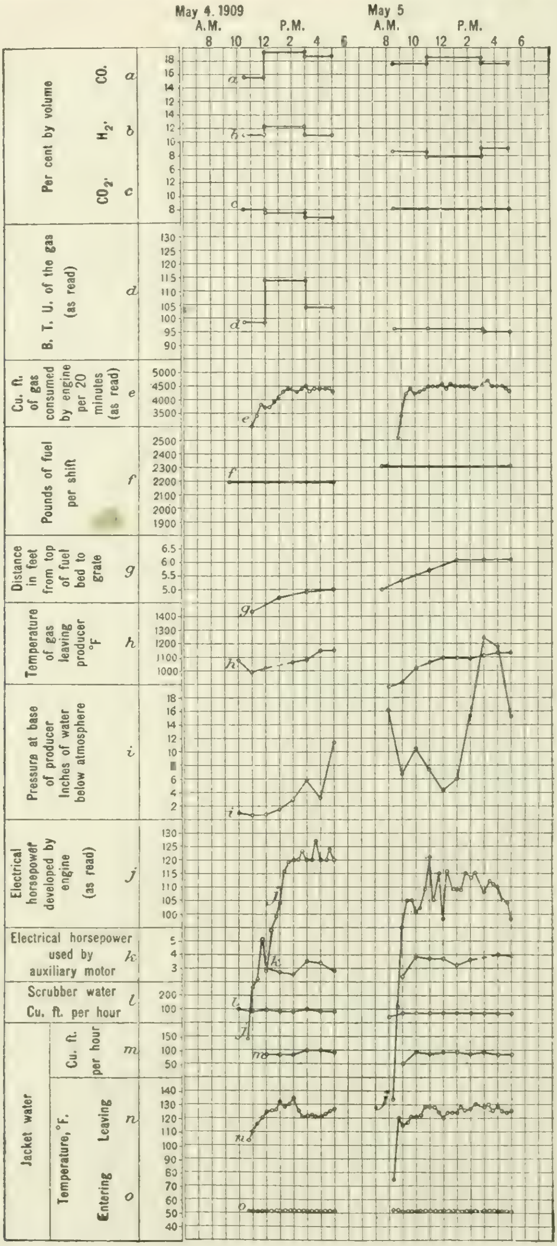


FIGURE 239.—Graphic log sheet, test No. 186, Pittsburg No. 12 coal.

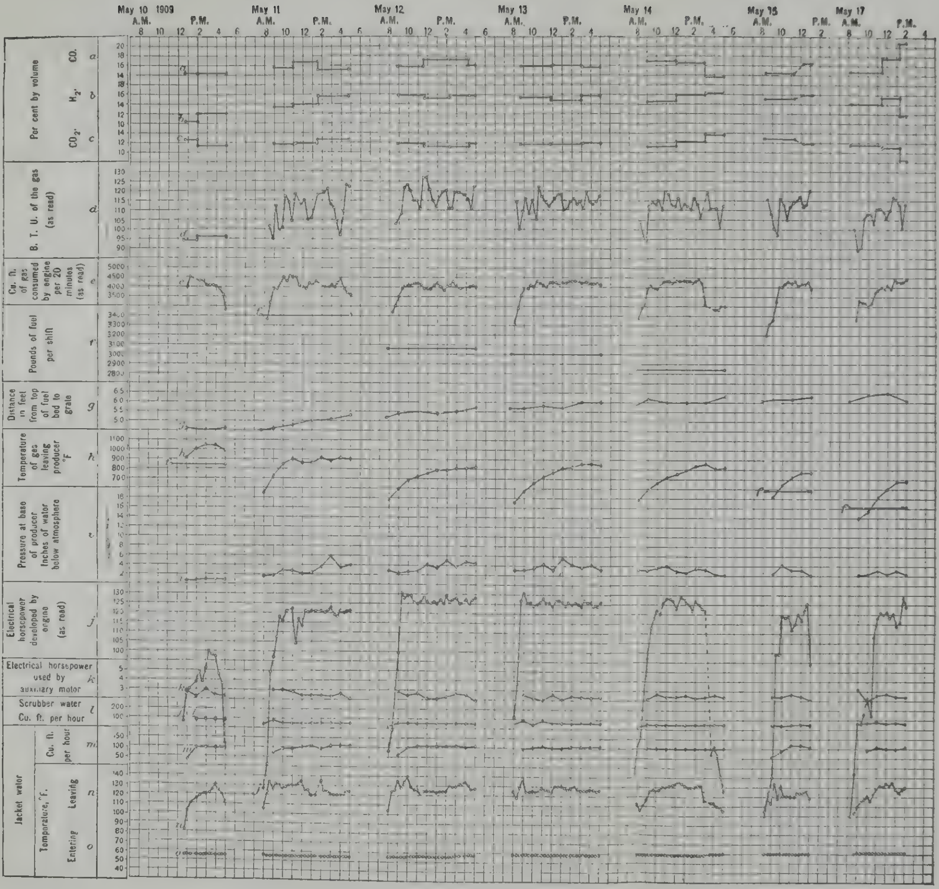
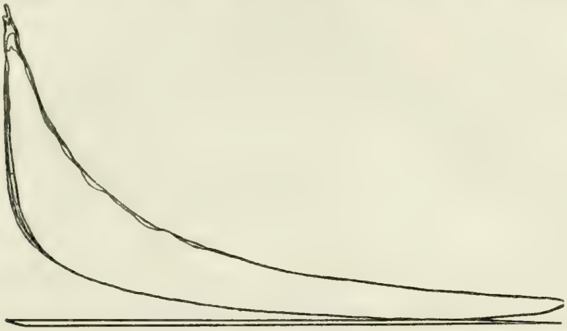


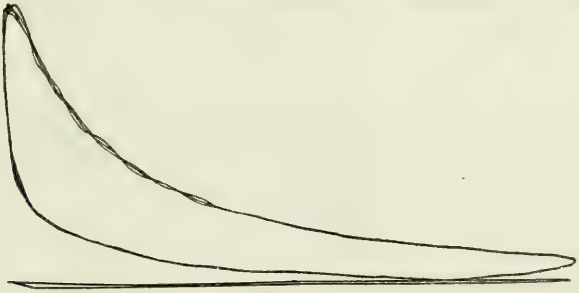
FIGURE 210.—Graphic log sheet, test No. 187, Pittsburg No. 11 coal.

87080°—Bull. 13—11. (To face page 340.)

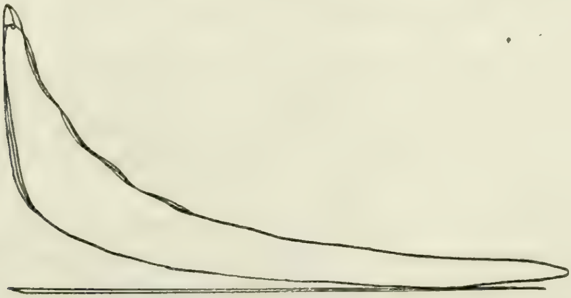
ducing no clinker. The lignite ignited very slowly when the fire was first lighted, but after the fuel bed was burning well it ignited readily. During the shutdown from one day's run to the next, the producer held fire remarkably well, and within 5 to 10 minutes after starting the exhauster, gas of good quality was available for the engine.



Right cylinder: Max. pres., 391 lbs., release, 26 lbs.; M. E. P., 68.5 lbs.; I. H. P., 57.2.



Center cylinder: Max. pres., 340 lbs.; release, 26 lbs.; M. E. P., 74.1 lbs.; I. H. P., 61.8.



Left cylinder: Max. pres., 351 lbs.; release, 30 lbs.; M. E. P., 65.9 lbs.; I. H. P., 55.0.

FIGURE 241.—Indicator cards taken May 12, 1909, 10.11 a. m., during gas-engine test No. 187, on Pittsburg No. 11 coal. Scale of spring, 200; revolutions per minute, 262.8.

The graphic log (fig. 240) shows the operating conditions. The irregularity of the load curves for the fifth and sixth days was due to a faulty igniter. On the sixth day of the run, Saturday, the plant was shut down at 1 o'clock and the producer was given no further attention until the following Monday morning. At this time the fuel bed was in excellent condition, and within 10 minutes after the gas exhauster was started gas of fair quality was available for the engine. The results of the test given in the table (p. 352) are based on the total fuel used during the 7 days' run, with no allowance made for stand-by losses. Graphic log is given on page 340.

Pittsburg No. 14, test 188.—A California lignite (the same as fired in run-of-mine form during test 185) was used in briquets for test 188. The briquets were hard, although made without a binder. In the producer they burned more readily than the same fuel in the run-of-mine form, and produced a gas of greater but more variable heat value. The briquetted fuel had a higher calorific power and contained much less moisture than when unbriquetted. In the producer the briquets fell to pieces as soon as they were heated through, forming a fuel bed of fine material looking much like sawdust. Throughout the test the resistance of the bed was exceptionally high in spite of frequent shots. There were also large accumulations of clinker, which helped to increase the resistance. Each morning it required from 20 to 45 minutes to generate gas of suitable quality for the engine. Graphic log is given on page 342.

Pittsburg No. 18, test 189.—The fuel used during this test was an Illinois bone coal, which, upon close examination, was found to consist of thin layers of good coal between layers of slate. In the producer it ignited readily and burned freely, but it had a tendency to slag, forming pasty masses of clinker. The gas produced was low in heat value, and but partial load could be maintained. This fuel did not hold fire well over night and it required some time each morning to get the producer into good condition. At the end of the fifth day the fuel bed was practically one mass of clinker, and no attempt was made to undertake another day's run. Graphic log is given on page 342.

Pittsburg No. 19A, test 190.—The fuel used during this test was a Rhode Island graphitic anthracite. It was heavy and hard and a freshly broken surface presented a glossy appearance; it contained a large percentage of graphite and one could mark with pieces of the coal as readily as with a pencil.

Because this fuel ignited slowly, the coke bed was allowed to become thoroughly incandescent before any of the graphitic coal was charged, and while the fuel bed was being built up a maximum draft was maintained. About an hour after the first charge of coal was made the gas burned steadily at the test cock, and although it was low in heat value the engine was started. After running about 30 minutes, however, on no load, it stopped, due to the poor quality of the gas. After the engine was started the draft in the producer decreased considerably on account of the small amount of gas consumed by the engine. With this reduced draft the fire died down and the gas

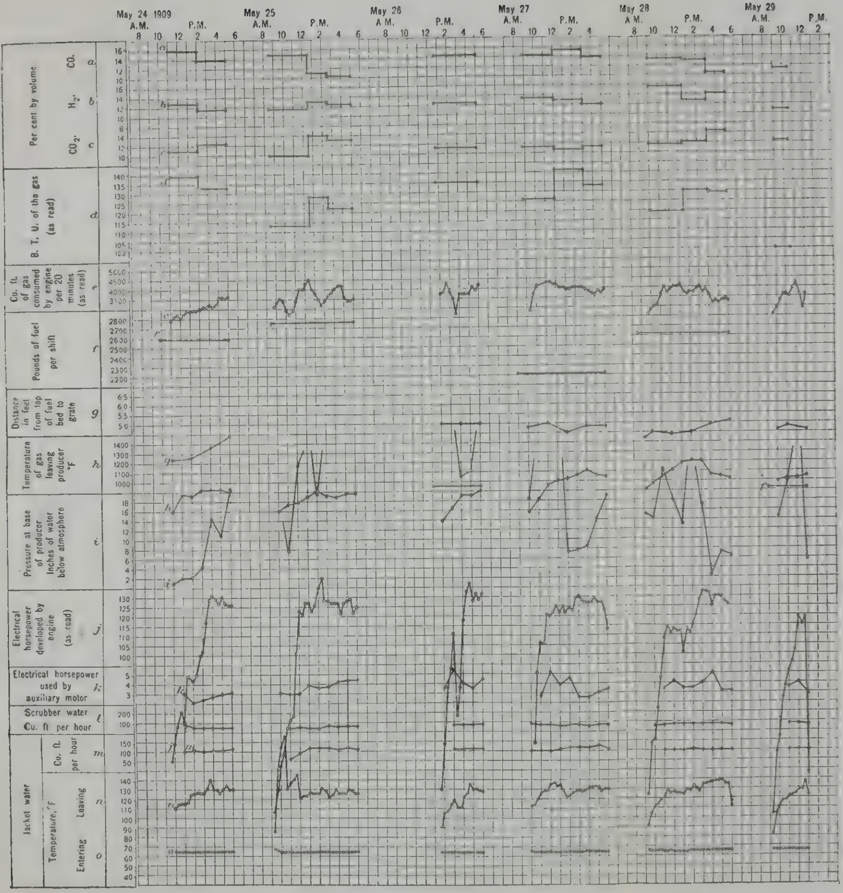


FIGURE 242.—Graphic log sheet, test No. 188, Pittsburg No. 14 coal.

87080°—Bull. 13—11. (To face page 342.) No. 1.

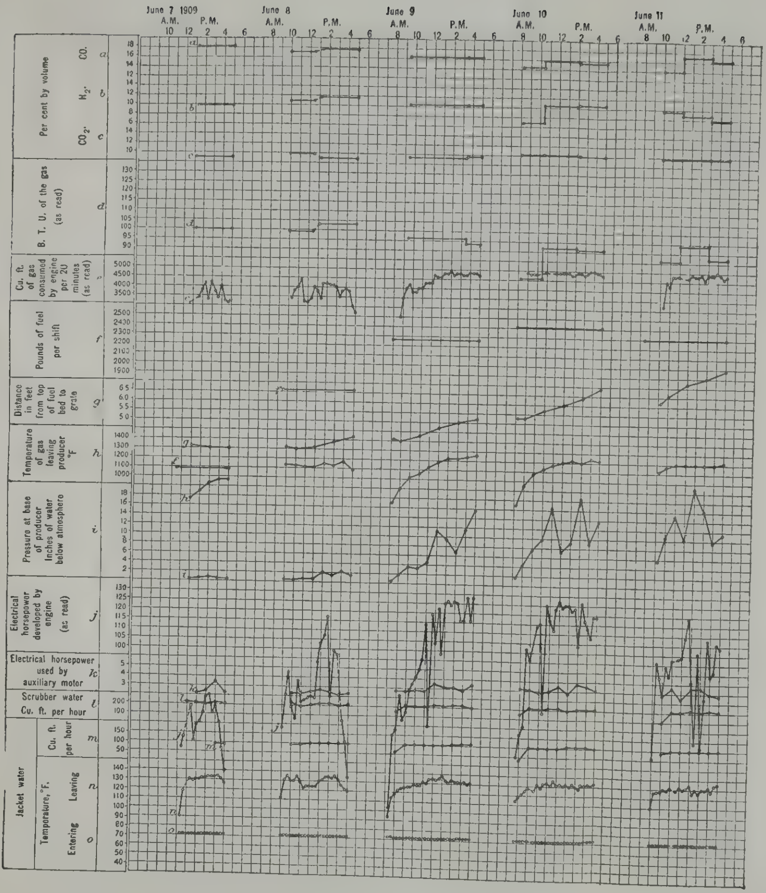
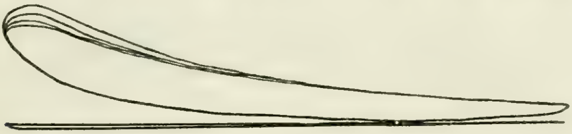


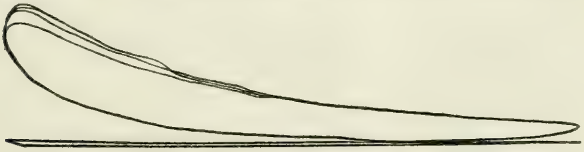
FIGURE 243.—Graphic log sheet, test No. 189, Pittsburg No. 18 coal.

87080°—Bull. 13—11. (To face page 342.) No. 2.

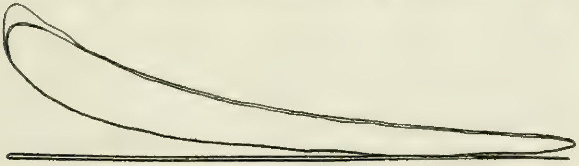
decreased rapidly in heat value. Soon after the engine stopped the gas was discharged into the atmosphere, and with a good draft the fire soon began to improve; the gas, however, was of unsatisfactory quality for some time. The engine was finally started again, and in order to maintain a sufficient draft to produce combustible gas a portion of the gas was allowed to escape through the purge pipe. During the remainder of the day (about 1½ hours) the producer gave no trouble and a little over half of full load was maintained at the engine. At the close of the day's run the producer was seemingly in good condition for the night's shutdown. The fire, however, did not keep, and the next morning it was necessary to rekindle it with wood. As is shown by the graphic log (fig. 245), the results obtained were more satisfactory after the first day's trial. From 1 to 2 hours each morning were required to get the producer in condition to generate gas of sufficient heat value to start the engine, and at the close of each day's run the fire was banked with a good grade of coal in order to hold it over night. Throughout the greater part of the test, also, a considerable portion of the gas was necessarily allowed to escape to the atmosphere in order to maintain the required draft. The quantity of gas thus wasted was difficult to estimate, and for this reason little value can be attached to the figures given in the table (p. 357) for fuel consumed per horsepower hour, since no allowance for this waste was made.



Right cylinder: Max. pres., 143 lbs., release, 17 lbs.; M. E. P., 41.0 lbs.; I. H. P., 34.6.



Center cylinder: Max. pres., 168 lbs.; release, 18 lbs.; M. E. P., 46.8 lbs.; I. H. P., 39.4.



Left cylinder: Max. pres., 184 lbs.; release, 16 lbs.; M. E. P., 47.3 lbs.; I. H. P., 39.8.

FIGURE 244.—Indicator cards taken June 9, 1909, 9.26 a. m., during gas-engine test No. 189, on Pittsburg No. 18 coal. Scale of spring, 200; revolutions per minute, 265.0.

Throughout the test the fuel bed increased rapidly in thickness, and at the end of the fourth day the producer was completely filled with fuel and refuse. One of the characteristics of this graphitic coal is that its ash occupies nearly the same volume as the original fuel.

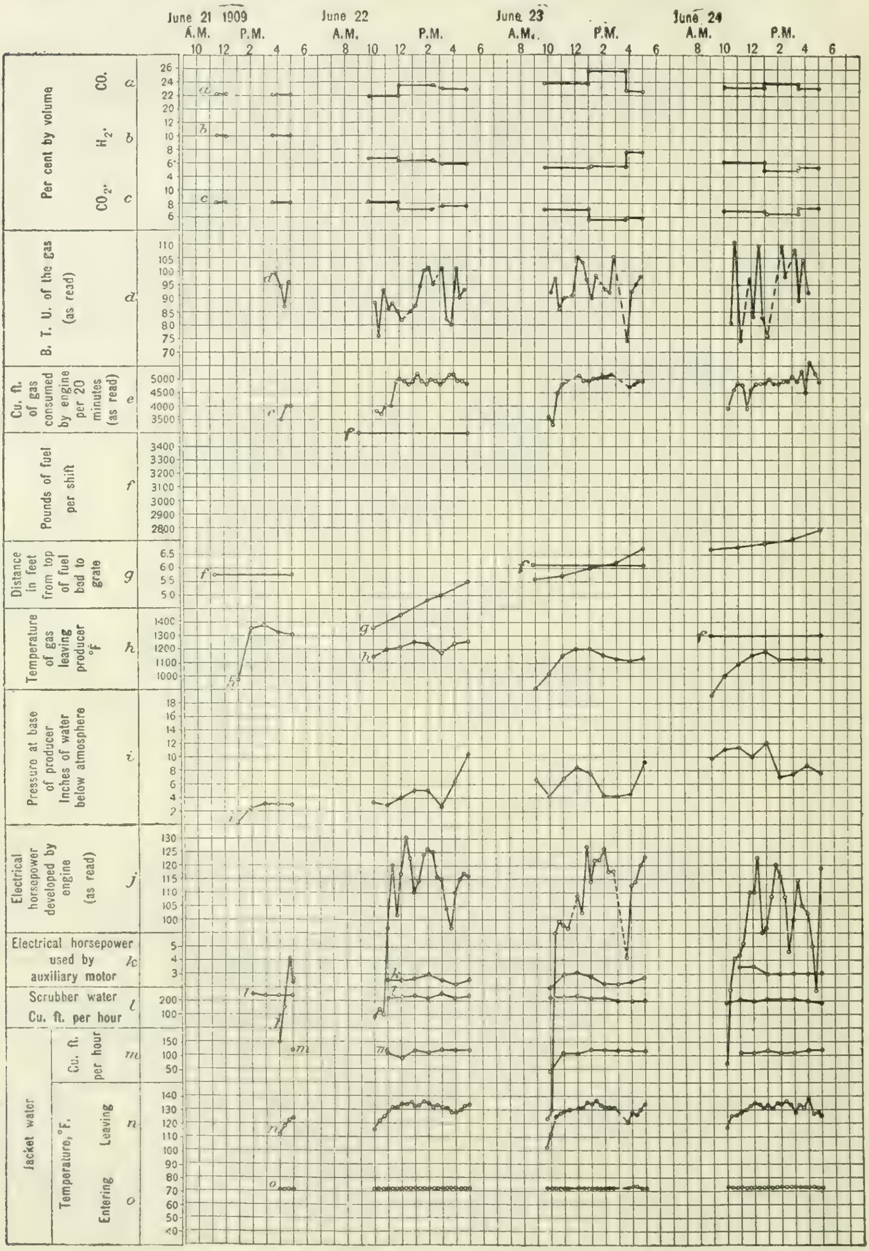


FIGURE 245. Graphic log sheet, test No. 190, Pittsburg No. 19A coal.

The resistance of the fuel bed was not excessive at any time, and few shots were made. Throughout the run little trouble was experienced from clinker, although a considerable quantity formed and adhered firmly to the producer walls. Graphic log is given on page 344.

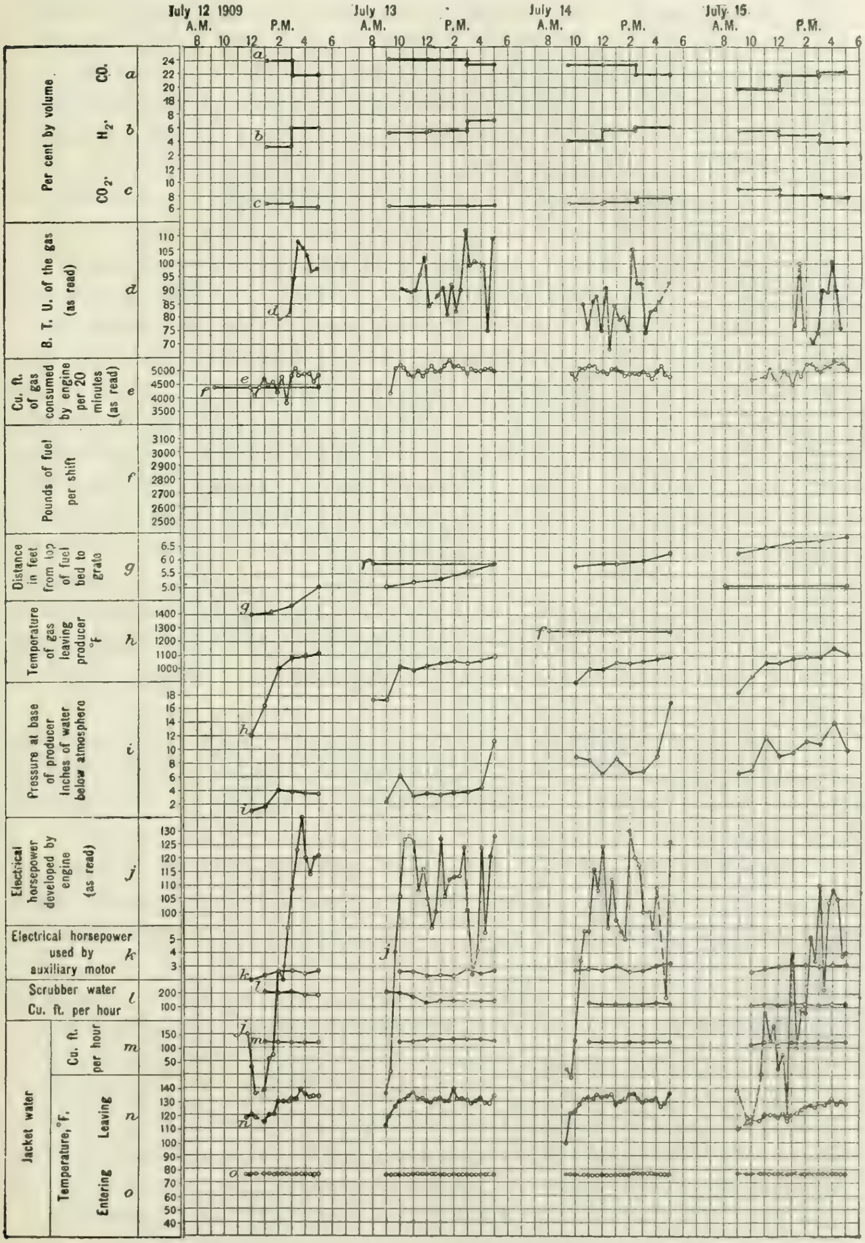


FIGURE 246.—Graphic log sheet, test No. 191, Pittsburg No. 19A coal.

Pittsburg No. 19A, test 191.—A second test was made on Pittsburg No. 19A in an attempt to reduce the waste of gas and thus obtain results that would be of more value than those obtained from test 190. Instead of kindling a fire on the coke bed, as in the preceding tests, 1,000 pounds of the graphitic coal, making a layer 1 foot thick, were first charged on top of the coke in the producer, and then the fire was started on top of this. The result of this change of procedure was satisfactory; gas of sufficient heat value to run the engine was generated in about an hour and a quarter from the time of starting the fire, and at the end of the test practically all of the coke was recovered. During the first 3 hours of the test no gas was discharged into the atmosphere, and consequently there was no waste, but at the end of this period the fire began to die out and the gas diminished in heat value. It was evident that the draft in the producer was too low; consequently a portion of the gas was allowed to escape, and soon afterwards the fuel bed was in much better condition and the heat value of the gas was considerably higher.

Throughout the test it was frequently necessary to resort to this method of increasing the draft in order to generate gas of sufficient heat value to run the engine. Nevertheless, the quantity of gas thus wasted was much less than in the preceding test, and from the results given in the table (p. 352) it may be seen that the fuel consumption was also much less. On the other hand, the effort to operate with a minimum waste of gas resulted in a much lower average draft than in the preceding test, and the effect of this was to lower the heat value of the gas and consequently to diminish the average load which could be carried at the engine.

The thickness of the fuel bed increased rapidly as in the preceding test, but during the last part of the run there was much more clinker formed than at any time during test 190. Graphic log is given on page 345.

Pittsburg No. 36, test 192.—The fuel used during test 192 was a Utah coal, which in appearance closely resembled the ordinary grades of run-of-mine bituminous coal. It contained a large percentage of slack and very small lumps.

In the producer this fuel burned readily, and with the characteristic odor of lignite. It showed no tendency to cake, but, on the other hand, thoroughly disintegrated soon after firing, giving the fuel bed an appearance not unlike a bed of hot sand. This coal was exceptionally high in volatile matter, and, although a thick coke bed was provided at the beginning of the test, a considerable quantity of tar was carried over with the gas. The top of the fuel bed was hot at all times, but the temperature in the lower portions, and especially in the coke bed, were evidently much below normal. The temperature of the gas leaving the producer was also lower than usual.

Although the tar in the gas caused the exhauster to stick at frequent intervals, at no time during the run did it occasion trouble at the engine. At the conclusion of the test, however, it was necessary to clean the tar from the engine valves and gas passages. The fact

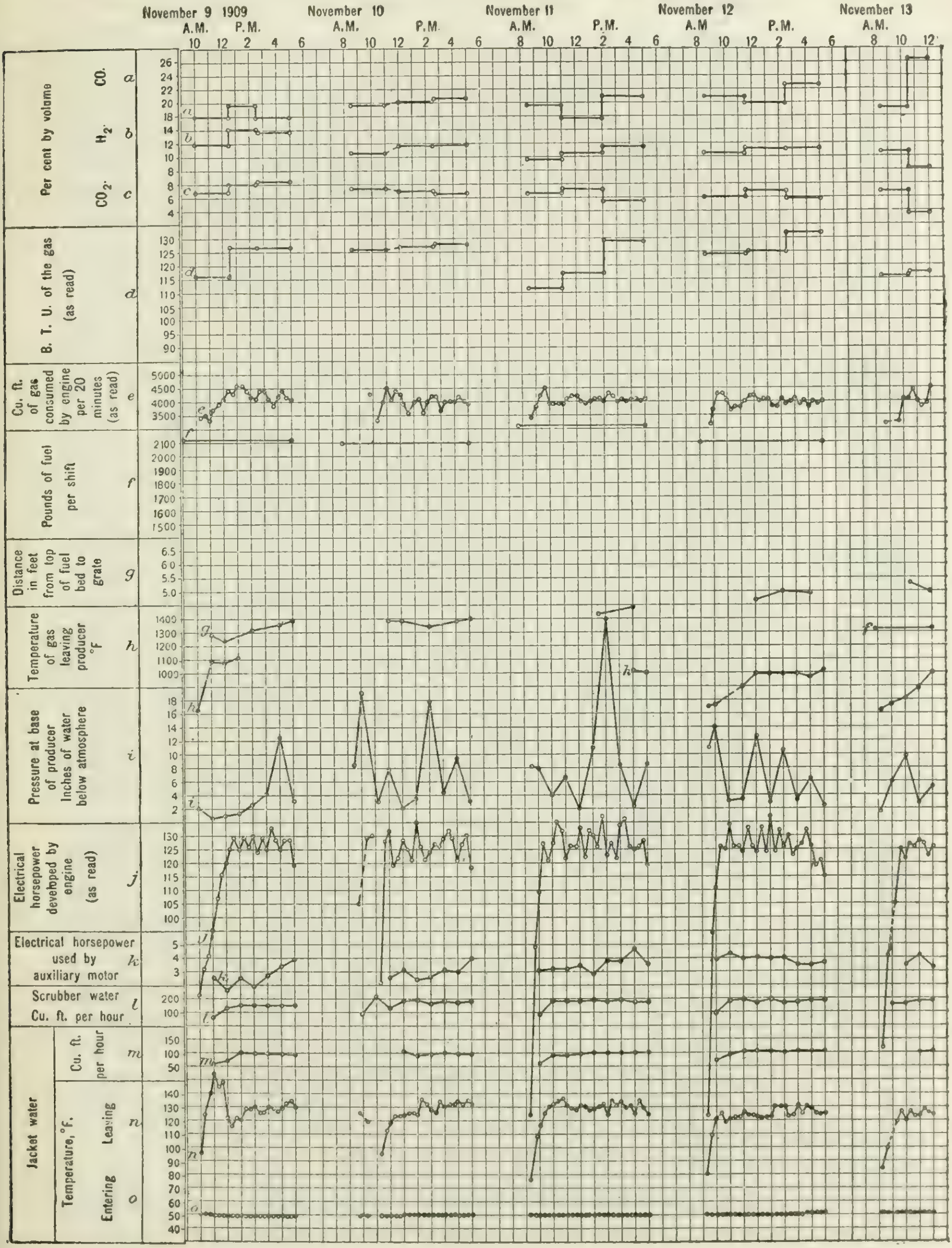


FIGURE 247.—Graphic log sheet, test No. 192, Pittsburg No. 36 coal.

that the coal was fine and had no tendency to cake caused the fuel bed to pack closely, and rendered necessary the shooting of the fuel bed at frequent intervals in order to keep its resistance from becoming excessive. Fire held overnight in the producer very well, but each morning it was necessary to run from half to three-quarters of an hour before the gas was of sufficiently good quality to operate the engine.

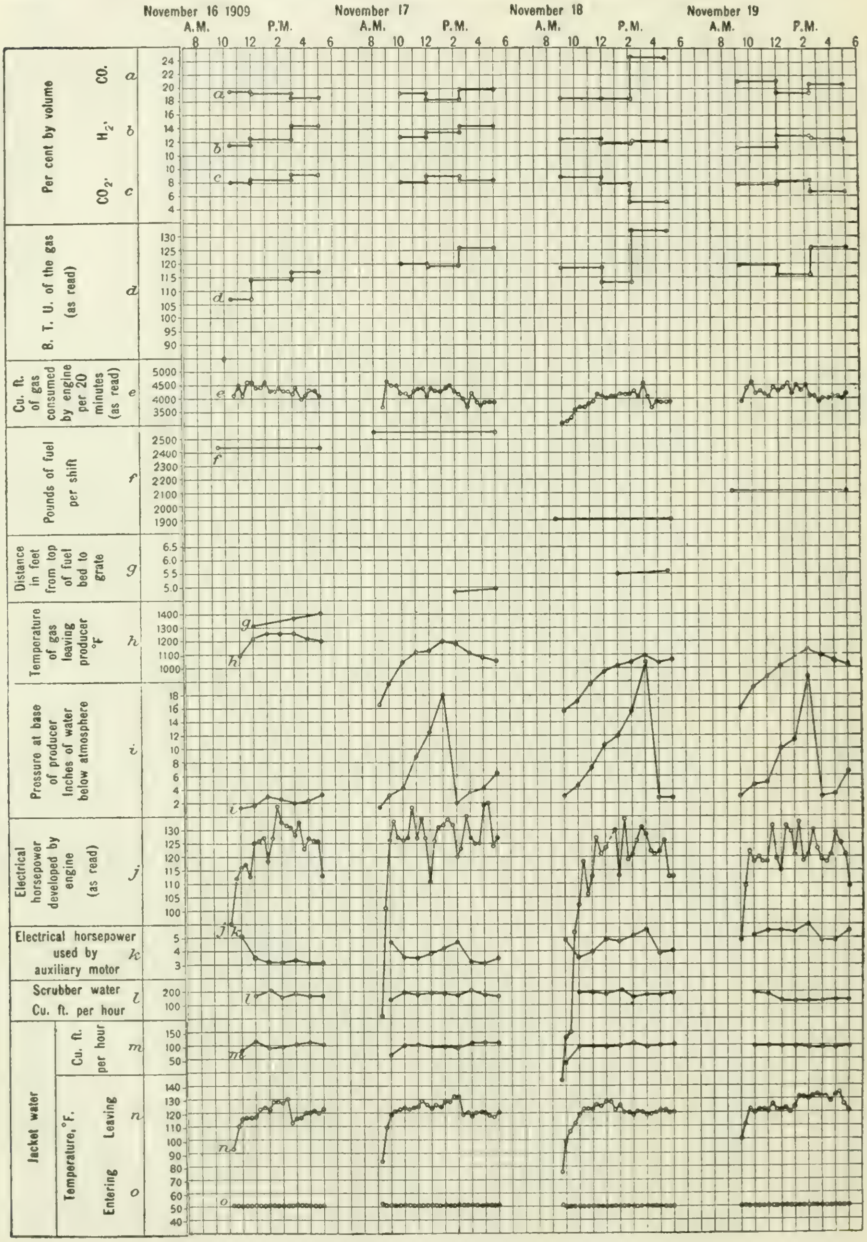


FIGURE 248.—Graphic log sheet, test No. 193, Pittsburg No. 35 coal.

After the fuel bed was in working condition, however, the gas was of fair quality and nearly full load was maintained at the engine. Practically no clinker formed during the test. Graphic log is given on page 347.

Pittsburg No. 35, test 193.—The fuel used during this test, a Washington coal, was rather fine, dry, and dusty. There were a few lumps, however, up to 4 or 5 inches in diameter, but they were very friable and were easily knocked to pieces. In the producer this fuel burned freely and without any tendency to cake. The producer required constant and careful watching, however, as the fuel bed had a tendency to burn through in places, forming channels or chimneys, and thus causing wide fluctuations in the quality of the gas. During the test the fuel bed held fire exceptionally well during the night, and each morning after the producer was started, from 10 to 15 minutes were usually sufficient to generate gas of good quality.

The engine ran steadily during the greater part of the run and carried nearly full load. A considerable quantity of clinker formed during the test, but it gave little trouble and was easily removed from the walls of the producer. Graphic log is given on page 348.

Pittsburg No. 62, test 194.—Pittsburg No. 62 was a graphitic anthracite from Rhode Island, having the same characteristics as Pittsburg No. 19A. It behaved in a similar manner in the producer, being slow to ignite and requiring a good draft to generate a gas of fair quality. As in previous tests with this fuel, a part of the gas was wasted during much of the time, and for this reason little value can be attached to the figures for fuel consumption per brake horsepower-hour given in the table on page 357. This graphitic coal would not hold fire overnight in the producer, and in order to avoid rekindling each morning the fire was banked at the end of each day's run with a good grade of bituminous coal, which held the fire satisfactorily. The coal thus used was reduced to its equivalent weight of graphitic coal and charged against the test. From 1½ to 2 hours each morning after starting the producer were required before a gas capable of running the engine was generated. Throughout the test the gas was rather variable in quality and the load carried was somewhat irregular, as is shown by the graphic log (fig. 249). A comparatively small amount of clinker formed during this run. Graphic log is given on page 350.

Pittsburg No. 71, test 195.—Pittsburg No. 71 was a Michigan peat which was delivered to the producer platform in lumps 2 to 2½ inches in diameter. These lumps were very firm and appeared to be dry. The test was begun in the usual manner, and about an hour after the first charge of peat was made the engine was started. Only a partial load could be carried at first, but as the fuel bed increased in thickness the gas improved in quality, and from time to time the load was increased until full load was easily carried.

During the first 2 hours of the run indications were favorable for a satisfactory test, but after this time the freshly fired peat ignited

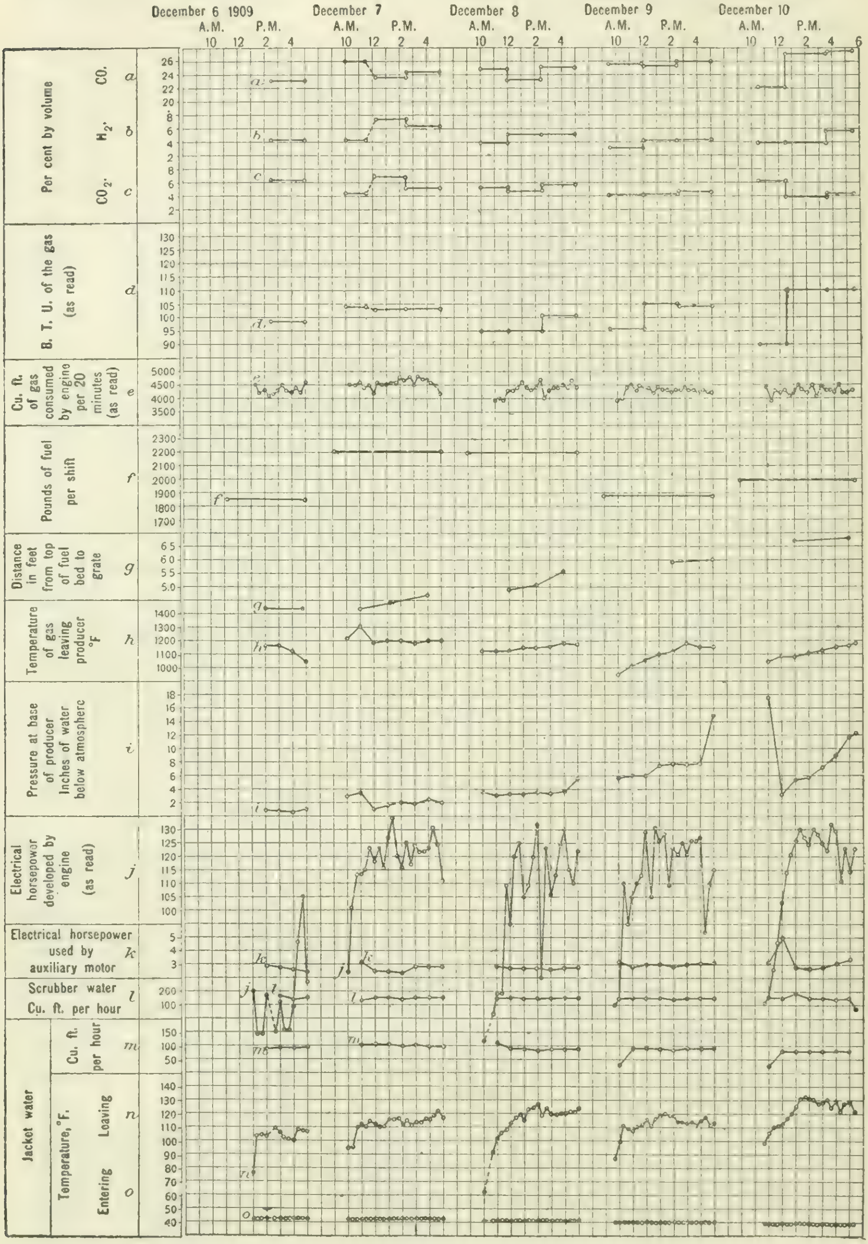


FIGURE 249.—Graphic log sheet, test No. 194, Pittsburg No. 62 coal.

slowly and the combustion zone gradually left the peat and descended to the coke bed. The lower part of the producer became highly

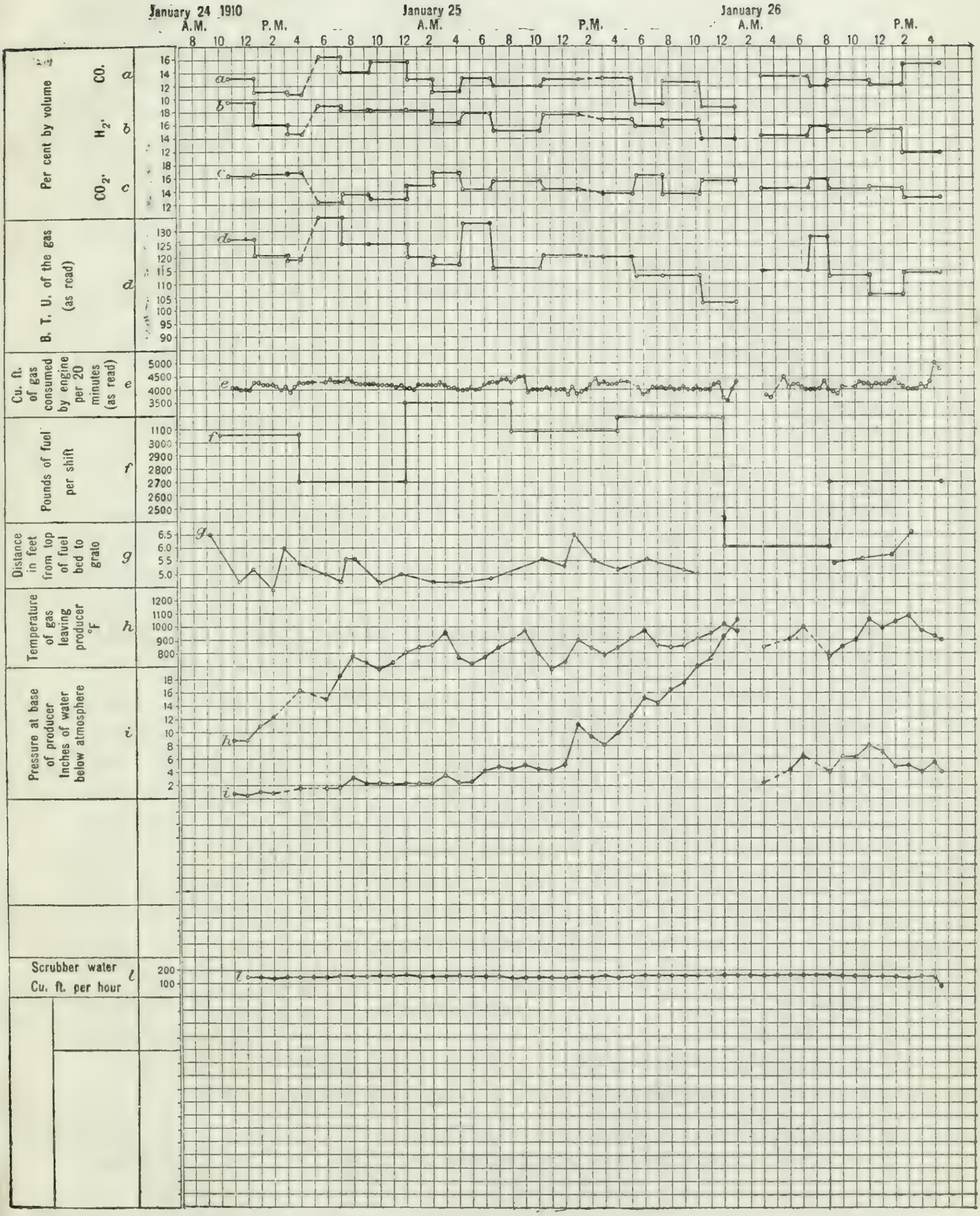


FIGURE 250.—Graphic log sheet, test No. 195, Pittsburg No. 71 coal.

87080°—Bull. 13—11. (To face page 350.)

heated, and the gas-outlet pipe and a portion of the economizer became red hot. It was at once evident that unless the combustion zone could be transferred from the coke to the peat a shut-down would be necessary. An effort was made to help conditions by shooting the fire, but this had little effect. Another method was then tried. Several hundred pounds of peat were fed into the producer at one time, and a wood fire which was replenished until the peat was well ignited was kindled on top of the charge. This process worked fairly well; the highly heated parts of the producer began to cool, and in a very short time conditions were normal. For a period of about 30 minutes following the rekindling of the peat the gas was of poor quality and would not burn steadily at the test cock; the engine, however, was not stopped, but it became necessary to take off most of the load. An hour after the peat was rekindled the gas was of good quality, and the engine ran steadily and carried full load.

After the producer had run satisfactorily for some time, freshly charged peat deadened the fire, and the combustion zone again descended to the coke bed, causing the heat value of the gas to decrease. A large quantity of peat was again charged and rekindled with wood, with practically the same results as before. This process was found necessary every 6 to 8 hours. The fire, once well started, would burn down through a body of peat and produce a gas of good and uniform quality. When the fire was rekindled, however, there was a period of about 45 minutes during which the gas decreased greatly in heat value, and practically all of the load had to be taken from the engine. After a continuous run of about 35 hours the test was abruptly brought to a close by the breaking of one of the engine cylinders. The operating conditions throughout the run were so erratic that the usual computations for a report were not attempted. The unusual behavior of the peat in the producer was undoubtedly caused by its high moisture content.

A sample of the peat taken at the car gave the following proximate analysis: Moisture, 57.16 per cent; volatile combustible matter, 25.02 per cent; fixed carbon, 11.23 per cent; ash, 6.59 per cent.

A second run was made upon this peat, but without the engine, the gas being metered and sampled and then burned. During the interval of about 3 weeks between the two runs, the peat was stored under cover. As a result, the peat was much drier during the second run, but in the producer, it behaved much the same as previously, and the fire was necessarily rekindled from time to time in the same manner as during the first run. A continuous test of over 50 hours was made, and except for brief periods at the rekindling of the fire the gas was of good quality. The report of the test is based upon the second run, as is also the graphic log. Graphic log is given on page 350.

Results of producer-gas tests made at Pittsburg.

Test No.	Designation of fuel.	Location of mine or deposit.	Duration of test (hours).	Proximate analysis of fuel (per cent).					Fuel charged in producer (pounds).[a]									Refuse.		
				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur, separately determined.	Total.			Per hour.			Per square foot of fuel-bed area per hour.			Total (determined by weight).	Combustible in refuse.	
									As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.		Total (lbs.).	Per cent.
1	2	4	5	11	12	13	14	15	16	17	20	21	22	23	27	28	29	19	30	31
	Pittsburg:																			
170	No. 1	Marianna, Pa	69.00	2.20	32.65	55.44	9.71	1.59	12,679	12,400	11,169	183.8	179.7	161.9	14.2	13.9	12.5	2,523	1,159	45.9
171	No. 1A	do	38.00	2.43	32.12	49.48	15.97	2.88	8,990	8,772	7,336	236.6	230.8	193.1	18.3	17.8	14.9	2,901	1,126	38.8
172	Slack	Madison, Pa	53.00	4.36	29.02	54.65	11.97	1.29	10,720	10,253	8,969	202.3	193.5	169.2	15.6	14.9	13.1	2,236	602	26.9
173	No. 4	Elizabeth City, N. C	13.48	13.88	36.64	21.70	27.78	1.17	5,925	5,103	3,457	440.0	379.0	256.0	34.0	29.2	19.8	2,256	523	23.2
174	Slack	Madison, Pa	64.00	3.79	29.47	55.76	10.98	1.61	11,661	11,219	9,939	182.2	175.3	155.3	14.1	13.5	12.0	1,241	257	20.7
175	No. 5A	Pocahontas, Va	110.92	1.79	15.41	65.89	16.91	.51	18,515	18,184	15,053	166.9	163.9	135.7	12.9	12.7	10.5	2,523	574	22.7
176	No. 5A	do	104.00	1.37	15.77	71.41	11.45	.48	16,670	16,442	14,533	160.3	158.1	139.7	12.4	12.2	10.8	2,731	736	26.9
177	No. 5A	do	103.17	1.92	15.11	68.47	14.50	.60	12,005	11,775	10,035	116.4	114.1	97.3	9.0	8.8	7.5	2,603	963	37.0
178	No. 5A	do	92.92	2.04	15.51	67.98	14.47	.56	11,399	11,166	9,517	122.7	120.2	102.4	9.5	9.3	7.9	2,077	378	18.2
179	No. 7	Rockdale, Tex	82.00	31.84	27.13	30.49	10.54	1.04	27,057	18,442	15,591	330.0	224.9	190.1	25.5	17.4	14.7	3,202	635	19.8
180	No. 8	Lytle, Tex	65.00	31.05	27.21	28.54	13.20	1.51	21,970	15,148	12,249	338.0	233.0	188.4	26.1	18.0	14.5	3,002	471	15.7
181	No. 9	Calvert, Tex	66.50	29.60	28.10	30.65	11.65	.95	21,810	15,354	12,813	328.0	230.9	192.7	25.3	17.8	14.9	3,871	567	14.6
182	No. 9	do	81.50	27.64	28.91	31.37	12.08	.92	22,763	16,471	13,722	279.3	202.1	168.4	21.6	15.6	13.0	2,903	428	14.7
183	No. 12	Walston, Pa	35.83	2.68	21.66	45.31	30.35	4.42	9,100	8,856	6,094	254.0	247.2	170.1	19.6	19.1	13.1	3,245	226	7.0
184	No. 13	Lehigh, N. Dak	46.67	34.91	27.17	30.84	7.08	.80	18,393	11,972	10,669	394.1	256.6	228.6	30.4	19.8	17.6	2,127	894	42.0
185	No. 14	Ione, Cal	34.50	37.81	31.77	17.00	13.42	.91	15,012	9,336	7,321	435.0	271.0	212.0	33.6	20.9	16.4	2,256	300	13.3
186	No. 12	Walston, Pa	15.00	2.25	22.00	43.86	31.89	6.43	5,031	4,918	3,314	335.4	327.9	220.9	25.9	25.3	17.0	2,462	516	21.0
187	No. 11	Scranton, N. Dak	51.00	34.66	27.35	30.74	7.25	.76	17,712	11,573	10,288	347.3	226.9	201.7	26.8	17.5	15.6	1,507	573	38.0
188	No. 14	Ione, Cal	39.67	10.16	44.79	27.08	17.97	1.52	12,631	11,348	9,078	318.4	286.1	228.8	24.6	22.1	17.7	2,138	722	33.8
189	No. 18	Sherrard, Ill	35.67	8.67	31.77	36.44	23.12	4.78	10,865	9,923	7,411	304.6	278.2	207.8	23.5	21.5	16.0	3,266	196	6.0
190	No. 19A	Auburn, R. I	22.33	3.70	2.11	71.45	22.74	.06	11,335	10,916	8,339	507.6	488.8	373.4	39.2	37.7	28.8	3,000	1,648	55.0
191	No. 19A	do	29.00	4.80	2.50	69.90	22.80	.10	9,454	9,000	6,844	326.0	310.3	236.0	25.2	24.0	18.2	2,138	845	39.5
192	No. 36	Coalville, Utah	35.53	11.67	39.05	44.08	5.20	1.44	9,642	8,517	8,015	271.4	239.7	225.6	20.9	18.5	17.4	1,758	1,242	70.6
193	No. 35	Tono, Wash	32.33	15.98	33.49	39.05	11.48	.54	10,434	8,767	7,569	322.7	271.2	234.1	24.9	20.9	18.1	1,626	715	44.0
194	No. 62	Portsmouth, R. I	32.17	11.50	3.41	63.59	21.50	.59	11,334	10,031	7,594	352.3	311.8	236.1	27.2	24.1	18.2	2,815	551	55.1
195	No. 71	Bancroft, Mich	52.48	40.13	36.15	15.76	7.96	.27	25,125	15,042	13,041	478.7	286.6	248.5	36.9	22.1	19.2	2,290	178	7.8

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[a] Figures given include the fuel equivalent of coke consumed during test.

Results of producer-gas tests made at Pittsburg—Continued.

Test No.	Designation of fuel.	Combustible consumed.		Coke in fixing bed (pounds).			Calorific value (British thermal units).												
							Fuel (per pound).			Standard gas.						Equivalent to stated horsepower per minute.			
		Total (pounds).	Per cent.	Total charged in producer.	Recovered from refuse.	Consumed during test.	As fired.	Dry.	Combustible.	From 1 pound of fuel.		Per cubic foot.	Consumed per horsepower hour.			Gas.	Indicated.	Brake.	Electrical.
										As fired.	Dry.		Indicated.	Brake.	Electrical.				
1	2	32	33	34	35	36	37	38	39	41	42	43	44	45	46	47	48	49	50
	Pittsburg:																		
170	No. 1	10,010	89.6	1,168	....	....	13,388	13,689	15,197	....	....	....	....	....	....	....	7,151	6,184	5,345
171	No. 1A	6,210	84.6	962	....	....	12,382	12,690	15,174	....	....	....	....	....	....	....	7,164	6,201	5,357
172	Slack	8,367	93.3	665	....	....	12,778	13,361	15,273	....	....	....	....	....	....	....	6,432	5,834	5,007
173	No. 4	2,934	84.9	696	....	....	5,974	6,937	10,240	3,423	3,971	109.7	9,829	11,639	13,625	25,067	6,486	5,711	4,906
174	Slack	9,682	97.4	704	....	....	13,041	13,554	15,300	6,850	7,124	109.6	9,184	11,179	13,382	20,811	5,760	4,735	3,953
175	No. 5A	14,479	96.2	650	....	....	12,762	12,994	15,698	9,170	9,330	114.2	9,353	10,929	12,653	25,495	6,931	5,930	5,124
176	No. 5A	13,797	94.9	750	....	....	13,725	13,916	15,743	9,381	9,512	118.9	9,203	10,749	12,437	25,070	6,931	5,930	5,124
177	No. 5A	9,072	90.4	1,026	233	793	13,145	13,401	15,725	8,040	8,207	110.9	9,061	12,243	15,437	15,607	4,377	3,241	2,570
178	No. 5A	9,139	96.0	1,107	195	912	13,138	13,412	15,735	8,996	9,177	113.3	9,313	11,987	14,548	18,394	5,022	3,902	3,215
179	No. 7	14,956	95.9	998	84	914	7,133	10,465	12,379	4,740	6,961	119.4	9,648	11,271	13,086	26,101	6,880	5,892	5,073
180	No. 8	11,778	96.2	1,011	477	534	6,957	10,089	12,478	4,263	6,186	109.3	9,061	10,635	12,384	24,026	6,737	5,743	4,933
181	No. 9	12,246	95.6	984	229	755	7,357	10,451	12,523	4,032	5,854	108.4	....	....	....	24,029	....	....	....
182	No. 9	13,294	96.9	1,718	978	740	7,416	10,249	12,305	4,716	6,519	106.7	....	....	....	21,946	....	....	....
183	No. 12	5,868	96.4	1,523	700	823	9,927	10,201	14,821	4,324	4,443	91.6	8,244	10,094	12,128	18,288	5,641	4,606	3,834
184	No. 13	9,775	91.6	a1,550	627	a923	6,885	10,577	11,867	3,596	5,517	111.0	9,346	11,111	12,998	23,593	6,419	5,400	4,615
185	No. 14	7,021	95.9	1,602	890	712	6,332	10,183	12,985	2,799	4,498	98.2	9,025	11,077	13,198	20,293	5,718	4,657	3,911
186	No. 12	2,798	84.5	1,559	1,140	419	9,623	9,844	14,609	3,722	3,813	100.6	8,561	10,281	12,102	20,818	6,180	5,149	4,373
187	No. 11	9,715	94.4	1,641	1,330	311	6,847	10,480	11,788	3,796	5,817	116.1	8,940	10,704	12,574	21,991	6,250	5,226	4,445
188	No. 14	8,356	92.0	1,118	817	301	9,538	10,617	13,271	4,777	5,321	126.7	8,907	10,693	12,607	21,562	6,155	5,124	4,344
189	No. 18	7,215	97.4	1,154	204	950	9,214	10,089	13,509	3,728	4,079	92.5	8,658	10,721	12,839	18,909	5,552	4,483	3,745
190	No. 19A	6,691	80.2	813	166	647	10,121	10,510	13,759	2,587	2,696	99.1	9,296	11,258	13,319	21,919	5,993	4,950	4,187
191	No. 19A	5,999	87.7	1,017	989	28	10,090	10,590	13,930	3,996	4,205	94.7	10,076	12,548	15,010	21,737	5,489	4,407	3,682
192	No. 36	6,773	84.5	1,178	996	182	11,054	12,514	13,297	5,441	6,167	123.1	9,134	10,660	12,408	24,622	6,850	5,870	5,043
193	No. 35	6,854	90.6	1.478	806	672	8,996	10,708	12,402	4,562	5,431	119.1	9,195	10,779	12,529	24,533	6,787	5,790	4,980
194	No. 62	6,043	79.6	1,435	673	762	10,440	10,523	13,898	3,777	4,262	101.0	8,989	10,757	12,625	22,161	6,269	5,238	4,462
195	No. 71	12,863	98.6	456	173	283	5,074	8,476	9,776	3,171	5,292	119.2	....	....	....	25,286	....	....	....

[a] Approximate.

Results of producer-gas tests made at Pittsburg—Continued.

Test No.	Designation of fuel.	Standard gas produced (cubic feet).					Standard gas consumed by engine (cubic feet).				Composition of gas (per cent of volume).						
		Total.	Per hour.	Per pound of fuel charged.			Per hour.	Per horsepower hour.			CO_2.	O_2.	C_2H_4.	CO.	H_2.	CH_4.	N_2.
				As fired.	Dry.	Combustible.		Indicated.	Brake.	Electrical.							
1	2	52	53	54	55	56	60	61	62	63	64	65	66	67	68	69	70
	Pittsburg:																
170	No. 1	903,545	13,095	71.2	72.9	80.9	13,085	77.6	89.7	103.8	....	....	....	....	....	....	....
171	No. 1A	522,800	13,758	58.2	59.6	71.3	13,748	81.4	94.0	108.9	....	....	....	....	....	....	....
172	Slack	696,939	13,150	65.0	68.0	77.7	13,140	81.8	95.5	111.3	....	....	....	....	....	....	....
173	No. 4	184,813	13,710	31.2	36.2	53.6	13,700	86.5	101.7	118.4	10.94	0.41	0.06	16.91	10.19	0.66	60.83
174	Slack	729,135	11,393	62.5	65.0	73.4	11,383	83.8	102.0	122.1	9.14	.14	.06	16.59	11.20	1.34	61.53
175	No. 5A	1,485,772	13,395	80.3	81.7	98.7	13,385	81.9	95.7	110.8	9.01	.22	.03	16.43	12.30	1.87	60.14
176	No. 5A	1,315,731	12,651	78.9	80.0	90.6	12,641	77.4	90.4	104.6	6.22	.13	.01	21.05	12.01	.49	60.09
177	No. 5A	871,213	8,444	72.5	74.0	86.8	8,434	81.7	110.4	139.2	7.07	.12	.01	19.67	10.44	.59	62.10
178	No. 5A	905,131	9,741	79.4	81.0	95.1	9,731	82.2	105.8	128.4	6.95	.29	.01	19.97	9.69	.64	62.45
179	No. 7	1,075,531	13,116	39.7	58.3	69.0	13,106	80.8	94.4	109.6	11.41	.26	.00	14.88	13.06	1.55	58.84
180	No. 8	857,304	13,189	39.0	56.6	70.0	13,179	82.9	97.3	113.3	11.32	.21	.11	15.34	13.28	1.34	58.40
181	No. 9	884,427	13,300	37.2	54.0	63.3	....	....	....	....	10.37	.24	.02	16.31	12.50	1.37	59.19
182	No. 9	1,005,800	12,341	44.2	61.1	73.3	....	....	....	....	10.78	.20	.00	16.23	12.56	1.19	59.04
183	No. 12	429,215	11,979	47.2	48.5	70.4	11,969	90.0	110.2	132.4	8.19	.34	.00	17.66	9.04	.70	64.07
184	No. 13	595,160	12,753	32.4	49.7	55.8	12,743	84.2	100.1	117.1	11.87	.01	.00	16.01	14.76	.98	56.37
185	No. 14	427,773	12,399	28.5	45.8	58.5	12,389	91.9	112.8	134.4	12.63	.03	.00	11.96	13.04	1.60	60.74
186	No. 12	186,238	12,416	37.0	37.9	56.2	12,406	85.1	102.2	120.3	7.80	.12	.00	17.95	10.00	.87	63.26
187	No. 11	579,618	11,365	32.7	50.1	56.3	11,355	77.0	92.2	108.3	11.69	.05	.00	16.05	14.64	1.48	56.09
188	No. 14	405,083	10,211	37.7	42.0	52.5	10,201	70.3	84.4	99.5	11.91	.25	.00	13.19	12.67	4.16	57.82
189	No. 18	437,502	12,265	40.3	44.1	59.0	12,255	93.6	115.9	138.8	9.63	.15	.00	16.23	9.75	.71	63.53
190	No. 19A	296,348	13,271	26.1	27.2	35.5	13,261	93.8	113.6	134.4	6.98	.13	.00	23.25	6.33	.38	62.93
191	No. 19A	399,379	13,772	42.2	44.4	58.4	13,762	106.4	132.5	158.5	7.24	.06	.00	22.74	5.28	.34	64.34
192	No. 36	426,395	12,001	44.2	50.1	53.2	11,991	74.2	86.6	100.8	6.66	.46	.10	20.18	11.21	1.89	59.49
193	No. 35	399,557	12,359	38.3	45.6	52.8	12,349	77.2	90.5	105.2	7.98	.25	.06	19.81	12.68	1.17	58.05
194	No. 62	423,526	13,165	37.4	42.2	55.8	13,155	89.0	106.5	125.0	5.08	.08	.00	24.91	4.66	.43	64.84
195	No. 71	668,515	12,738	26.6	44.4	51.3	....	....	....	....	14.83	.75	.08	12.69	16.39	2.26	53.00

Results of producer-gas tests made at Pittsburg—Continued.

Test No.	Designation of fuel.	Water used.												Average barometric pressure (inches of mercury).	Average pressure (inches of water).					
		Vaporizer (pounds).			Wet scrubber (cubic feet).			Engine jackets (cubic feet).			Entire plant (cubic feet).				Gas leaving producer.	Gas leaving economizer.	Gas leaving wet scrubber.	Gas entering dry scrubber.	Gas entering meter.	Gas leaving meter.
		Total.	Per hour.	Per pound of fuel fired.	Total.	Per hour.	Per 1,000 cu. ft. standard gas.	Total.	Per hour.	Per brake-horse-power hour.	Total.	Per hour.	Per brake-horse-power hour.							
1	2	71	72	73	74	75	79	81	82	83	84	85	86	87	89	90	91	92	93	94
	Pittsburg:																			
170	No. 1	1,302	18.9	0.10	11,044	160	12.2	8,825	128	0.88	19,890	288	1.98	29.01	− 6.60	− 6.98	−11.63	+ 5.67	+3.54	+2.04
171	No. 1A	1,095	28.8	.12	5,921	156	10.1	4,466	118	.80	10,405	274	1.87	29.38	−12.04	−12.23	−17.83	+ 6.93	+3.47	+1.94
172	Slack	2,584	48.7	.24	8,383	158	12.0	5,200	98	.71	13,624	257	1.87	29.39	− 8.20	− 8.91	−15.13	+ 7.49	+3.64	+2.09
173	No. 4	[a] 143	......	......	1,835	136	9.9	1,568	116	.86	3,405	253	1.88	29.38	− 9.36	− 9.68	−10.28	+ 8.01	+3.45	+1.95
174	Slack	2,684	42.0	.23	10,181	159	13.6	6,878	108	.96	17,102	267	2.36	29.33	− 7.85	− 8.18	−14.24	+ 7.55	+3.73	+2.42
175	No. 5A	5,748	51.8	.31	15,931	144	10.7	9,724	88	.63	25,747	232	1.66	29.26	− 8.91	− 9.14	−16.24	+ 5.20	+3.58	+1.92
176	No. 5A	5,317	51.1	.32	15,276	147	11.6	8,484	82	.58	23,845	229	1.64	29.25	− 8.46	− 8.65	−15.50	+ 5.21	+3.75	+2.19
177	No. 5A	3,757	36.4	.31	13,961	135	16.0	6,628	64	.84	20,649	200	2.62	29.22	− 7.26	− 7.44	−12.94	+ 5.16	+3.99	+2.72
178	No. 5A	3,493	37.6	.31	7,341	79	8.1	8,200	89	.97	15,597	168	1.82	29.20	− 6.46	− 6.64	−12.00	+ 5.39	+3.87	+2.52
179	No. 7	[a] 125	......	......	7,311	89	6.8	6,716	83	.60	14,029	171	1.23	29.13	−17.76	−17.98	−23.89	+ 5.18	+3.48	+1.69
180	No. 8	[a] 741	......	......	5,075	78	5.9	5,526	85	.63	10,613	163	1.21	29.25	−18.26	−18.57	−25.15	+ 5.15	+3.48	+1.91
181	No. 9	0	.0	.00	4,610	69	5.2	......	......	......	......	......	......	29.19	−14.96	−15.00	−21.14	+ 5.85	+4.12	+2.42
182	No. 9	0	.0	.00	5,228	64	5.2	......	......	......	......	......	......	29.23	−10.03	−10.48	−11.67	+ 6.46	+4.72	+3.21
183	No. 12	1,528	42.6	.17	2,969	83	6.9	3,715	104	.95	6,708	187	1.72	29.16	−11.07	−11.31	−14.62	+ 4.70	+3.60	+2.01
184	No. 13	[a] 174	......	......	2,961	63	5.0	5,031	108	.85	7,995	171	1.35	29.13	− 3.40	− 3.72	− 5.02	+ 5.11	+3.54	+1.92
185	No. 14	0	.0	.00	2,563	74	6.0	3,238	96	.87	5,801	168	1.53	28.99	− 2.48	− 2.83	− 4.28	+ 5.22	+3.41	+1.98
186	No. 12	384	25.6	.08	1,364	91	7.3	1,243	85	.70	2,613	174	1.43	29.06	− 8.96	− 9.40	−13.26	+ 5.30	+3.28	+1.76
187	No. 11	0	.0	.00	3,336	65	5.8	4,998	99	.80	8,334	163	1.32	29.24	− 3.02	− 3.25	− 4.66	+ 5.05	+3.51	+2.10
188	No. 14	1,400	35.3	.11	3,810	96	9.4	3,996	105	.87	7,828	197	1.63	29.16	− 7.93	− 8.11	−10.20	+ 5.14	+3.59	+2.44
189	No. 18	1,696	47.6	.16	7,647	214	17.5	3,522	99	.93	11,196	314	2.97	29.21	− 6.80	− 6.99	−10.83	+ 5.44	+3.26	+1.42
190	No. 19A	1,015	45.5	.09	6,296	282	21.3	2,557	115	.98	8,869	397	3.40	29.18	− 6.21	− 6.57	−10.68	+ 5.55	+2.97	+ .62
191	No. 19A	1,054	36.3	.11	4,503	155	11.3	3,382	121	1.16	7,902	273	2.62	29.12	− 6.99	− 7.24	−10.04	+ 6.04	+2.93	+ .39
192	No. 36	1,519	42.8	.16	6,817	192	16.0	3,500	99	.71	10,341	291	2.10	29.58	− 6.75	− 7.21	− 9.50	+ 5.57	+3.43	+2.48
193	No. 35	[a] 83	......	......	6,210	192	15.5	3,186	99	.72	9,397	291	2.13	29.28	− 6.41	− 6.85	− 9.29	+ 5.82	+3.33	+2.24
194	No. 62	[a] 153	......	......	5,371	167	12.7	2,866	89	.72	8,239	256	2.07	29.20	− 4.77	− 5.09	− 7.59	+ 6.14	+3.37	+1.85
195	No. 71	0	.0	.00	8,271	158	12.4	......	......	......	......	......	......	29.21	− 6.94	− 7.17	−10.88	+10.12	+4.56	+2.93

[a] Vaporizer used only part of test.

Results of producer-gas tests made at Pittsburg—Continued.

Test No.	Designation of fuel.	Average temperatures (° F.).								Gas horsepower.	Revolutions per minute of gas engine.	Explosions per minute per cylinder.	Indicated horsepower.												
		Air entering economizer.	Air and vapor entering producer.	Gas leaving producer.	Gas leaving economizer.	Gas leaving wet scrubber.	Gas entering meter.	Jacket water.					Indicator-card pressures (pounds per square inch).									Cylinder 1.	Cylinder 2.	Cylinder 3.	Total.
								Entering.	Leaving.				Maximum.			At release.			Mean effective pressure.						
													Cylinder No. 1.	Cylinder No. 2.	Cylinder No. 3.	Cylinder No. 1.	Cylinder No. 2.	Cylinder No. 3.	Cylinder No. 1.	Cylinder No. 2.	Cylinder No. 3.				
1	2	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
	Pittsburg:																								
170	No. 1	....	412	....	569	....	....	a 56	137	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	168.6
171	No. 1A	....	422	....	....	....	....	a 50	131	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	168.9
172	Slack	....	408	....	615	57	52	47	122	....	265.4	132.7	....	....	....	....	....	....	....	....	....	....	....	....	160.7
173	No. 4	....	432	....	....	86	....	88	144	591.0	262.6	131.3	....	....	....	....	....	....	....	....	....	....	....	....	158.3
174	Slack	82	417	1,540	610	64	60	56	122	490.7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	135.8
175	No. 5A	81	392	1,208	603	56	56	43	127	601.1	265.0	132.5	322	320	327	25.8	27.8	27.8	60.8	64.7	68.4	51.1	55.4	59.0	163.4
176	No. 5A	74	366	1,242	528	52	53	38	129	591.0	266.0	133.0	325	294	306	23.5	26.0	25.0	61.7	64.9	66.9	52.0	54.5	56.5	163.4
177	No. 5A	67	297	1,013	431	51	51	37	133	368.0	269.5	134.7	....	....	....	....	....	....	....	....	....	....	....	....	103.2
178	No. 5A	79	335	1,149	500	64	53	55	131	433.7	267.9	133.9	....	....	....	....	....	....	....	....	....	....	....	....	118.4
179	No. 7	73	451	1,275	649	49	48	38	135	615.3	261.9	131.0	....	....	....	....	....	....	....	....	....	....	....	....	162.2
180	No. 8	79	461	1,279	626	51	58	38	132	566.4	261.4	130.7	....	....	....	....	....	....	....	....	....	....	....	....	158.9
181	No. 9	77	464	1,180	600	55	51	....	....	566.5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
182	No. 9	84	448	1,088	567	57	53	....	....	517.4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
183	No. 12	82	383	1,194	539	62	57	48	116	431.1	261.4	130.7	....	....	....	....	....	....	....	....	....	....	....	....	133.0
184	No. 13	79	389	965	533	61	60	52	125	556.2	261.9	130.9	....	....	....	....	....	....	....	....	....	....	....	....	151.4
185	No. 14	80	423	1,033	564	62	59	53	124	478.4	254.6	127.3	....	....	....	....	....	....	....	....	....	....	....	....	134.8
186	No. 12	82	371	1,102	559	61	59	49	131	490.8	263.1	131.6	....	....	....	....	....	....	....	....	....	....	....	....	145.7
187	No. 11	81	337	767	467	66	70	57	132	518.5	262.9	131.5	....	....	....	....	....	....	....	....	....	....	....	....	147.4
188	No. 14	85	304	969	434	70	75	64	134	508.3	263.0	131.5	....	....	....	....	....	....	....	....	....	....	....	....	145.1
189	No. 18	97	366	1,152	518	79	79	72	136	445.8	262.0	131.0	....	....	....	....	....	....	....	....	....	....	....	....	130.9
190	No. 19A	110	391	1,214	616	81	85	72	137	516.8	261.2	130.6	....	....	....	....	....	....	....	....	....	....	....	....	141.3
191	No. 19A	103	363	1,048	543	80	85	76	135	512.5	260.7	130.4	....	....	....	....	....	....	....	....	....	....	....	....	129.4
192	No. 36	75	269	957	401	57	62	48	133	580.5	272.3	136.2	....	....	....	....	....	....	....	....	....	....	....	....	161.5
193	No. 35	74	354	1,067	473	55	54	49	128	578.4	270.1	135.0	....	....	....	....	....	....	....	....	....	....	....	....	160.0
194	No. 62	64	400	1,180	516	47	43	39	119	522.5	268.8	134.4	....	....	....	....	....	....	....	....	....	....	....	....	147.8
195	No. 71	67	357	831	455	47	39	....	....	596.1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

a Approximate.

Results of *producer-gas tests made at Pittsburg*—Continued.

Test No.	Designation of fuel.	Brake horsepower.		Electrical horsepower.		Average electrical horsepower required to run auxiliary machinery.	Economic results: Fuel charged in producer per horsepower-hour (pounds).														
							Per indicated horsepower developed.			Per brake horsepower.						Per electrical horsepower.					
		Developed at engine.	Commercially available.	Developed at switchboard.	Commercially available.		As fired.	Dry.	Combustible.	Developed at engine.			Commercially available.			Developed at switchboard.			Commercially available.		
										As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.	As fired.	Dry.	Combustible.
1	2	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138
	Pittsburg:																				
170	No. 1	145.8	143.3	126.0	123.8	2.2	1.09	1.07	0.96	1.26	1.23	1.11	1.28	1.25	1.13	1.46	1.43	1.28	1.48	1.45	1.31
171	No. 1A	146.2	142.7	126.3	123.3	3.0	1.40	1.37	1.14	1.62	1.58	1.32	1.66	1.62	1.35	1.87	1.83	1.53	1.92	1.87	1.57
172	Slack	137.6	133.6	118.1	114.7	3.4	1.26	1.20	1.05	1.47	1.41	1.23	1.51	1.45	1.27	1.71	1.64	1.43	1.76	1.69	1.48
173	No. 4	134.7	131.0	115.7	112.5	3.2	2.78	2.39	1.62	3.27	2.81	1.90	3.36	2.89	1.95	3.80	3.28	2.21	3.91	3.37	2.28
174	Slack	111.6	109.7	93.2	91.6	1.6	1.34	1.29	1.14	1.63	1.57	1.39	1.66	1.60	1.42	1.95	1.88	1.67	1.99	1.91	1.70
175	No. 5A	139.8	136.1	120.8	117.6	3.2	1.02	1.00	.83	1.19	1.17	.97	1.23	1.21	1.00	1.38	1.36	1.12	1.42	1.39	1.15
176	No. 5A	139.8	136.1	120.8	117.6	3.2	.98	.97	.86	1.15	1.13	1.00	1.18	1.16	1.03	1.33	1.31	1.16	1.36	1.34	1.19
177	No. 5A	76.4	72.4	60.6	57.4	3.2	1.13	1.11	.94	1.52	1.49	1.27	1.61	1.58	1.34	1.92	1.88	1.61	2.03	1.99	1.70
178	No. 5A	92.0	88.0	75.8	72.5	3.3	1.04	1.02	.87	1.33	1.31	1.11	1.39	1.37	1.16	1.62	1.59	1.35	1.69	1.66	1.41
179	No. 7	138.9	134.3	119.6	115.6	4.0	2.03	1.39	1.17	2.38	1.62	1.37	2.46	1.67	1.42	2.76	1.88	1.59	2.85	1.95	1.64
180	No. 8	135.4	130.6	116.3	112.2	4.1	2.13	1.47	1.19	2.50	1.72	1.39	2.59	1.78	1.44	2.91	2.00	1.62	3.01	2.08	1.68
181	No. 9					3.2															
182	No. 9					2.7															
183	No. 12	108.6	103.6	90.4	86.2	4.2	1.91	1.86	1.28	2.34	2.28	1.57	2.45	2.39	1.64	2.81	2.73	1.88	2.95	2.87	1.97
184	No. 13	127.3	124.5	108.8	106.4	2.4	2.60	1.69	1.51	3.10	2.01	1.80	3.17	2.06	1.84	3.62	2.36	2.10	3.70	2.41	2.15
185	No. 14	109.8	106.7	92.2	89.6	2.6	3.23	2.01	1.57	3.96	2.47	1.93	4.08	2.54	1.99	4.72	2.94	2.30	4.85	3.02	2.37
186	No. 12	121.4	117.4	103.1	99.7	3.4	2.30	2.25	1.52	2.76	2.70	1.82	2.86	2.79	1.88	3.25	3.18	2.14	3.36	3.29	2.22
187	No. 11	123.2	120.4	104.8	102.4	2.4	2.36	1.54	1.37	2.82	1.84	1.64	2.88	1.88	1.68	3.31	2.17	1.92	3.39	2.22	1.97
188	No. 14	120.8	116.6	102.5	98.9	3.6	2.19	1.97	1.58	2.64	2.37	1.89	2.73	2.45	1.96	3.11	2.79	2.23	3.22	2.89	2.31
189	No. 18	105.7	102.2	88.3	85.4	2.9	2.33	2.13	1.59	2.88	2.63	1.97	2.98	2.72	2.03	3.45	3.15	2.35	3.57	3.26	2.43
190	No. 19A	116.7	113.4	98.7	95.9	2.8	3.59	3.46	2.64	4.35	4.19	3.20	4.48	4.31	3.29	5.14	4.95	3.78	5.29	5.10	3.89
191	No. 19A	103.9	100.7	86.8	84.1	2.7	2.52	2.40	1.82	3.14	2.99	2.27	3.24	3.08	2.34	3.76	3.57	2.72	3.88	3.69	2.81
192	No. 36	138.4	134.4	118.9	115.5	3.4	1.68	1.48	1.40	1.96	1.73	1.63	2.02	1.78	1.68	2.28	2.02	1.90	2.35	2.08	1.95
193	No. 35	136.5	131.5	117.4	113.1	4.3	2.02	1.70	1.46	2.36	1.99	1.72	2.45	2.06	1.78	2.75	2.31	1.99	2.85	2.40	2.07
194	No. 62	123.5	120.1	105.2	102.3	2.9	2.38	2.11	1.60	2.85	2.52	1.91	2.93	2.60	1.97	3.35	2.96	2.24	3.44	3.05	2.31
195	No. 71																				

Results of producer-gas tests made at Pittsburg—Continued.

Test No.	Designation of fuel.	Efficiency (per cent).									Page on which notes appear.
		Of conversion and cleaning gas.	Of producer plant.	Thermal, based on stated horsepower and gas horsepower.			Of entire plant, based on fuel charged per stated horsepower per hour.				
				Indicated.	Brake.	Electrical.	B. H. P. developed at engine.	B. H. P. commercially available.	E. H. P. developed at switchboard.	E. H. P. commercially available.	
1	2	156	157	158	159	160	161	162	163	164	167
	Pittsburg:										
170	No. 1						15.1	14.7	13.0	12.8	324-325
171	No. 1A						12.7	12.4	11.0	10.7	325-326
172	Slack						13.5	13.2	11.6	11.3	326-328
173	No. 4	57.2	56.9	26.8	22.8	19.6	13.0	12.7	11.2	10.9	328-329
174	Slack	52.6	52.4	27.6	22.8	19.0	12.0	11.8	10.0	9.8	329
175	No. 5A	71.8	71.4	27.2	23.2	20.1	16.8	16.2	14.5	14.0	329
176	No. 5A	68.4	68.0	27.6	23.7	20.4	16.1	15.7	13.9	13.6	329-330
177	No. 5A	61.2	60.7	28.1	20.8	16.5	12.7	12.0	10.1	9.5	330
178	No. 5A	68.5	67.9	27.3	21.2	17.5	14.6	13.9	12.0	11.5	330-331
179	No. 7	66.5	66.1	26.4	22.6	19.4	15.0	14.5	12.9	12.5	331-332
180	No. 8	61.3	60.9	28.1	23.9	20.5	14.6	14.1	12.6	12.2	333-334
181	No. 9	54.8	54.5								334
182	No. 9	63.6	63.3								334
183	No. 12	43.5	43.1	30.9	25.2	21.0	11.0	10.5	9.1	8.7	334-336
184	No. 13	52.2	51.9	27.2	22.9	19.6	11.9	11.7	10.2	10.0	336-338
185	No. 14	44.2	44.0	28.2	23.0	19.3	10.2	9.9	8.5	8.3	338
186	No. 12	38.7	38.4	29.7	24.7	21.0	9.6	9.3	8.1	7.9	338-339
187	No. 11	55.5	55.2	28.4	23.8	20.2	13.2	12.9	11.2	11.0	339-342
188	No. 14	42.6	42.3	28.5	23.8	20.2	10.1	9.8	8.6	8.3	342
189	No. 18	40.4	40.2	29.4	23.7	19.8	9.6	9.3	8.0	7.7	342
190	No. 19A	25.6	25.5	27.3	22.6	19.1	5.8	5.6	4.9	4.8	342-345
191	No. 19A	39.7	39.4	25.3	20.3	16.9	8.0	7.8	6.7	6.5	345-346
192	No. 36	49.2	49.0	27.8	23.8	20.5	11.8	11.4	10.1	9.8	346-349
193	No 35	50.7	50.3	27.7	23.6	20.3	12.0	11.6	10.3	9.9	349
194	No. 62	36.2	36.0	28.3	23.6	20.1	8.6	8.3	7.3	7.1	349
195	No. 71	62.5									349

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